Vegetation Assessment of Forests of Pagan Island, Commonwealth of the Northern Mariana Islands

Linda W. Pratt

U.S. Geological Survey, Pacific Island Ecosystems Research Center
Hawai`i Volcanoes National Park, HI 96718

December 2010

The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the U. S. Government. Mention of trade names or commercial products does not constitute their endorsement by the U. S. Government.

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (Continued)

Page

EXECUTIVE SUMMARY

As part of the Marianas Expedition Wildlife Surveys-2010, the forest vegetation of the island of Pagan, Commonwealth of the Northern Mariana Islands (CNMI), was sampled with a series of systematic plots along 13 transects established for monitoring forest bird populations. Shrubland and grassland were also sampled in the northern half of the island. Data collected were woody plant density, tree diameter at breast height, woody plant density in height classes below 2 m, and ground cover measured with the point-intercept method. Coconut forests (*Cocos nucifera*) were generally found to have low native tree diversity, little regeneration of trees and shrubs in the forest understory, and little live ground cover. The sole exception was a coconut-dominated forest of the northeast side of the island that exhibited high native tree diversity and a large number of young native trees in the understory. Ironwood (*Casuarina equisetifolia*) forests on the northern half of the island were nearly monocultures with almost no trees other than ironwood in vegetation plots, few woody plants in the understory, and low ground cover dominated by native ferns. Mixed native forests of both northern and southern sections of the island had a diversity of native tree species in both the canopy and the sparse understory. Ground cover of native forests in the north had a mix of native and alien species, but that of the southern half of the island was dominated by native ferns and woody plants.

During vegetation surveys in June-July 2010, 215 vascular plant species were observed on Pagan; 21 new island records of alien plants and 12 new island records of native plants were documented. Many of the new and recently sighted alien plants of the northern section of the island appeared to be in the incipient stage of invasion. Most of the new native plant sightings and a number of other rare tree and shrub species of Pagan were limited to forests of the rugged southern half of the island.

INTRODUCTION

The island of Pagan is the largest of the Mariana Islands north of Saipan and has an area of 48 km^2 (Mueller-Dombois and Fosberg 1998). Topographically, Pagan is composed of 2 active volcanoes (one in each of the northern and southern parts of the island) connected by a rocky isthmus. The island was settled by 1,500 BC by Micronesian people, who practiced aqriculture and cultivated plants (Bellwood 1989). It is likely that the original inhabitants altered the original vegetation, at least near the coast. During the early 20^{th} century, Japanese settlers had farms on the island, and many areas with suitable soils were intensively cultivated and delineated with windbreaks (Fosberg and Corwin 1958).

The vegetation of the island has been sporadically examined since the late 1800s, and based on published accounts and brief surveys in the 1930s, 1940s and 1950, Fosberg (1960) and Fosberg and Corwin (1958) described the vegetation of the island as it appeared approximately 60 years ago. Forests were patchy and included thickets of broad-leaved trees, mixed scrub forest, stands of ironwood, *Casuarina equisetifolia*, and plantations of coconut, *Cocos nucifera*. Much of the island was covered by grassland of the native swordgrass, *Miscanthus floridulus*, either in pure stands or mixed with scattered trees, and lava flows of the northern half of the island were often nearly bare of vegetation. Fosberg (1958) listed 168 species and varieties of vascular plants present on Pagan in 1950 and recognized 101 of these as indigenous. This checklist was subsequently updated and annotated (Fosberg *et al.* 1975).

In 1981, a large eruption occurred on Mt. Pagan, the volcano of the northern half of the island (Evans *et al*. 1987). At this time the human population was evacuated from the island, and few people have subsequently lived on Pagan. In addition to this major eruption, there have been small eruptive events on Pagan that have produced ash and steam (National

Aeronautics and Space Administration 2009). The eruption of 1981 eliminated much of the vegetation previously described for the northern part of the island, and there was apparently little re-vegetation for almost 2 decades following the eruption, apart from an increase in ironwood tree cover (Mueller-Dombois and Fosberg 1998). Feral goats (*Capra hircus*), pigs (*Sus scrofa*), and cattle (*Bos taurus*) are present on the island, and browsing damage has led to removal of natural vegetation (Cruz *et al*. 2000), vegetation degradation, and loss of native species (Mueller-Dombois and Fosberg 1998).

Early plant surveys of Pagan were of brief duration and qualitative in nature (Fosberg 1958). More recent vegetation surveys focused on wildlife habitat in remnant forest vegetation and used rapid assessment techniques (Cruz *et al.* 2000). The vegetation survey described in this report was part of the Marianas Expediition Wildlife Surveys of 2010 (MEWS 2010), a U.S. Fish and Wildlife Service (USFWS) project funded by the Department of Defense-U.S. Marines. The objectives of the 2010 vegetation survey of Pagan island (23 June-9 July) were to quantitatively sample the primary vegetation types on the island with repeatable vegetation plots; collect data on species composition, woody plant density, and ground cover; update the known checklist of vascular plants present on the island; and document newly established alien plant species. Emphasis was given to the forest vegetation that was also the focus of forest bird surveys. The survey was carried out at the beginning of the wet season, and most plants bore flowers or fruits.

THE STUDY AREA

Pagan Island is located about midway in the chain of the Mariana Islands north of Saipan at approximately 18^{o} north latitude and 145^{o} east longitude. Agrigan is the nearest island to the north and Alamagan is next in the island

chain to the south. Pagan is composed of a northern portion approximately 5 km east to west by 6 km north to south, connected to the narrow southern part of the island by a rough, low isthmus (Mueller-Dombois and Fosberg 1998). The northern portion is dominated by the active Mt. Pagan, whose circular caldera encompasses most of the northern island. Remnants of the old caldera wall are seen as prominent vegetated cliffs in the northern part of the island.

Lava flows erupted in 1981 cover the northern and southern slopes of Mt. Pagan, and much of the remaining northern section of the island is covered by historic and recent flows dated to a few hundred years. Thick ash and tephra deposits blanket most of the northern part of the island, particularly on the western and southern slopes (Trusdell *et al*. 2006). Only the far southern slope and patches of land on the northeastern side of the island predate the caldera (Fosberg and Corwin 1958), which formed about 1,000 years ago (Trusdell *et al*. 2006). The isthmus connecting the 2 parts of the island and the southern tip of the island are old substrates predating the caldera, while the summit peaks and western slope of the southern part of the island are of more recent origin (Fosberg and Corwin 1958). Limestone is present only on the northern part of the island in the form of raised coastlines in the far north and south (Fosberg 1960).

The climate of Pagan is tropical with little seasonal variation in monthly temperature, which ranges between 24^{o} and 27^{o} C. Precipitation is seasonal with a rainy season from July to October (Mueller-Dombois and Fosberg 1998). Average annual rainfall is 178-203 cm on Pagan (Corwin *et al*. 1957 cited by Trusdell *et al.* 2006). The northeast trade winds are relatively constant, and typhoons occur with high frequency (Mueller-Dombois and Fosberg 1998).

METHODS

Sampling Design

The focus of the vegetation sampling was forest vegetation in areas that were also sampled for forest birds (by other biologists of the Marianas Expedition Wildlife Surveys). Thirteen transects were placed in accessible forests of both northern and southern sections of the island (Fig. 1) by biologists of the U.S. Fish and Wildlife Service (Marshall and Amidon 2010). Transects 1-8 and 14 were placed on the northern part and transects 9, 10, 11, and 11-north were on the narrow southern part of the island. On the northern section transect 1 followed the southern part of the old caldera wall, and transect 2 curved around a rocky ridge to the east of the wall. Transect 3 was on a coastal shelf southwest of the caldera wall, camp, and the old village. Transect 14 was placed at Degusa (Regusa) Beach on the southern coast of the northern section. Transect 4 sampled the southwest slope of Mt. Pagan, and transect 5 was placed on the western side of the island north of Sanhiyong Lake. Transect 6 was on the northwest slope of the northern section, and transect 7 was just above Talague Beach in the far north. Transect 8 sampled 2 patches of forest in the northeastern part of the island.

In the southern part of the island, transects 9, 9 supplemental, and 10 were on the western slope of the southern peaks, and transects 11 and 11-north were placed on a plateau in the center of the island (Fig. 1). Transect 11 ran east to west at the base of a cliff face on the central plateau, and transect 11-north ran to the north of the cliff on the west side of the peaks. There were no transects 12 or 13. Transect 15, on the island's southern tip, was not sampled with vegetation plots.

Figure 1. Survey transects on Pagan Island, Mariana Islands (CNMI) in 2010 (Map by Fred Amidon, U.S. Fish and Wildlife Service.)

Stations for bird sampling were established at intervals of 150 m along transects. The starting point for vegetation sampling plots was determined by randomly selecting one of the 11-12 stations on each transect. On the northern part of the island, every third station was sampled systematically, counting from the randomly selected station, for a total of 36 forest plots. On the southern part of the island, every other station was sampled for vegetation. To increase the number of forest vegetation plots on the southern section, an additional 3 supplemental plots were selected near transect 9 at random distances (within 150 m) from the transect line and along an access trail between transects 9 and 10; the total number of forest plots in the south was 19. This scheme resulted in each of the transects (except for transect 15) sampled with 4 vegetation plots.

Forest bird transects sampled only forest vegetation, but shrubland and grassland vegetation types of the northern section of the island were examined with supplemental plots in areas adjacent to transects and access roads. Three shrubland plots were selected in that vegetation type by measuring from transect 2 stations to randomly selected points due north of that transect. Five grassland plots were placed at random distances measured from randomly selected points along the jeep road that stretched from the airstrip and main camp to the south coast at Degusa Beach. Two grassland plots were placed north and 3 south of the old caldera wall. Global positioning system (GPS) points were taken at each shrubland and grassland plot. Appendix I presents UTM coordinates for all vegetation plots along forest bird transects and supplemental shrubland and grassland plots.

At each selected transect station or grassland/shrubland point, a vegetation plot 10 x 20 m was placed centered on the station or random point, and the plot sides were measured out using standard 30-m tape measures. The long axis of the plot ran north/south and the short side of the plot (10m) ran east/west as measured with a magnetic compass. Within the 10 x 20 m vegetation plot (200 m^2) all tree and shrub species above 2 m in height were

counted, and their diameters at breast height (dbh) were measured using a dbh tape at 1.5 m from the ground. When trees had multiple stems, only the largest-diameter trunk was measured. After measuring dbh, each tree was marked with chalk to avoid recounting.

Woody plants below 2 m in height were counted in a subplot 10 x 10 m in size (100 m^2), selected by a coin toss to determine which half of the vegetation plot was sampled. Woody plants below 2 m tall were counted in height classes of 0.1-0.5 m, >0.5-1.0 m, and >1-2 m. For compilation purposes, the 2 smaller height classes were later combined.

Ground cover was measured on 2 randomly selected 20-m lines in each vegetation plot. Two points on the 10-m-long side of the plot were randomly selected, and this line placement was repeated at every plot sampled. A 20-m measuring tape or marked poly line was run between the same randomly selected points on the east/west lines of the vegetation plot. Using an aluminum tent pole, the point-intercept method (Mueller-Dombois and Ellenberg 1974) was employed to collect ground cover data along the two 20-m lines of each plot. Ground cover below 1 m height was measured systematically at 20-cm intervals (5 points/m) along each 20-m line, for a total of 100 points/line and 200 points per vegetation plot. Each species hit by the pole was recorded, along with bare exposed soil, rock, and litter. Litter included detached leaves, twigs, and woody debris. Only the first hit of the pole was counted. Species present in the ground cover of vegetation plots but not hit were recorded with negligible cover (0.1%). Unidentified species were collected and determined in camp. The identities of 2 grasses remain unknown.

During 3 weeks field work on the island, all plant species seen while traveling to transects and vegetation plots were recorded. A list of vascular plant species previously sighted or collected on the island was prepared prior to arrival on Pagan, and notes were taken of current localities of observed plants. Plant

species thought to be new records for the island and unidentified plants were collected, and specimens were prepared using field presses; specimens will be deposited at the Bishop Musuem *Herbarium Pacificum* in Honolulu. Several sites of special interest that were not surveyed with transects were visited, and plant species present were recorded. Surveyed sites included Sanhiyong Lake on the western shore of the northern part of the island; Sanhalom Lake, the only surface water of the island interior; the shoreline at Inae Dikiki, a prominent bay on the southeast coast of the northern part of the island; and recent lava flows of the north slope of Mt. Pagan.

Data Compilation

For each plot, the number of trees counted and the measured diameter at breast height were used to calculate basal area for each woody plant species that occurred in sample plots. Basal area was calculated by the formula pi(r^2), where r or radius equals half the diameter at breast height. The mean basal area for each tree species (in cm^2) was determined for each transect and the plot tree counts were pooled for each transect. Dominance of each species on the pooled plots of each transect was calculated by multiplying the number of trees of a given species in all 4 plots (density per 800 m^2) by the mean basal area of the species, and dominance ranks were assigned on the basis of this dominance value (Mueller-Dombois and Ellenberg 1974). For the 3 supplemental plots near transect 9, the density was calculated for 600 m^2. Dominance of each species was also calculated in m^2 and extrapolated to a hectare by multiplying the area covered per 800 m^2 by 12.5.

To determine stand structure of the forest of selected transects, the number of trees was counted in diameter classes in 5-cm increments for each species. The mean number of trees in each diameter class of a tree species was

determined for each transect by dividing the transect total by the number of plots (200 m^2) sampled per transect (4 except for transect 9 supplemental plots). These diameter class means were graphed for all tree species in selected transects.

Woody plant density for plants <2 m was presented as means of the number of plants per species in 2 height classes within the 10 x 10 m subplots of each of the 4 vegetation plots of each transect. The field data collected for height classes 0.1-0.5 and >0.5-1.0 m were combined into a height class of 0.1-1.0 m for presentation in the report. The second height class was that of woody plants >1-2 m tall.

Ground cover data were compiled for each plant species in each plot of a given transect. The points hit for a species in a plot (out of a total of 200 points/plot) were pooled for the 4 plots of each transect (3 plots each in transect 9 supplemental and shrubland and 5 plots in grassland). Percentage cover was determined by dividing the number of points hit for a species in the pooled plots by the total of all sampled points in the plots combined for a transect.

RESULTS

Coconut Forest of Northern Pagan

Five transects were used to sample coconut, *Cocos nucifera,* forest on the northern part of the island (Fig. 1.); these forests result from previous cultivation of coconut on the island. Transects 3 and 14 were on the southern edge of the northern section; transect 3 was on a coastal shelf just south of the old caldera wall, and transect 14 was at Degusa Beach between the shore and the southern slope of this part of the island. The remaining three transects were placed in coconut forest of the northern edge of the island; transect 7 was above Talague

Beach in the far north, and transect 6 was on the northwest slope of the island. Transect 8 crossed 2 remnant forest patchess in the extreme northeast corner of the island.

Tree density, basal area, and dominance - The dominant tree of all 5 transects was the introduced coconut, which consistently had the highest density on each transect, ranging from 15 to 54 trees in the 4 pooled plots (each 200 m^2 for a total of 800 m^2). In each transect, coconut trees had the greatest mean basal area of any tree species, typically 10 times greater than that of the second-ranked tree species (Table 1).

Tree species composition varied among the 5 transects. The native coral tree, *Erythrina variegata*, was the second-ranked tree of transect 3 plots with few, very large individuals. *Casuarina equisetifolia*, ironwood, was prominent in plots of transect 6 in the northwest, and *Hibiscus tiliaceus* (*pago*) formed thickets in transect 7 forest of Talague in the north. Transect 6 plot stand structure indicated multiple size classes for ironwood, indicating some reproduction of that species (Fig. 2). Transect 8 in the northeast of the island had the highest species diversity among coconut forest transects, with 8 native tree species represented beneath the coconut trees. In plots of transect 8, the native trees *Aglaia mariannensis* (*manpunyao*) and *Psychotria mariana* (*aploghating*) were present in multiple size classes (Fig. 3), indicating that *Aglaia*, at least, may have the capacity to recruit young trees and increase its population.

Plots of transect 14 above Degusa Beach supported a few large individuals of the native coastal tree *Barringtonia asiatica* (*puting* or fish-kill tree), as well as numerous native thicket-forming *Hibiscus tiliaceus*, and single individuals of the native trees *Morinda citrifolia* (Indian mulberry) and *Terminalia catappa* (Pacific almond) (Table 1).

Table 1. Density, Mean Basal Area, and Dominance of Tree Species in Plots (800m^2/transect) of Coconut Forest on Northern Pagan.

Transect/Species	MeanBA (cm^2)	#trees	Dominance (cm^2/800m^2)	Dominance (m^2/ha)	Rank
TR 3 All Plots (4)					
Cocos nucifera	583.42	42	24503.53	30.63	1
Erythrina variegata	6045.69	3	18137.06	22.67	2
Hibiscus tiliaceus	43.41	3	130.23	0.16	4
Terminalia catappa	1645.77	2	3291.54	4.11	3
TR 6 All Plots (4)					
Casuarina equisetifolia	231.03	15	3465.45	4.33	2
Cocos nucifera	687.40	15	10311.00	12.89	1
Psidium guajava	5.72	12	68.64	0.09	3
Terminalia catappa	7.07	1	7.07	0.01	4
TR 7 All Plots (4)					
Casuarina equisetifolia	167.33	1	167.33	0.21	4
Cocos nucifera	506.26	33	16706.49	20.88	1
Hibiscus tiliaceus	123.39	24	2961.26	3.70	2
Neisosperma oppositifolia	181.66	4	726.64	0.91	3
Psychotria mariana	5.42	2	10.84	0.01	5
TR 8 All Plots (4)					
Aglaia mariannensis	59.72	34	2030.46	2.54	2
Cocos nucifera	452.61	54	24440.78	30.55	1
Ficus prolixa	924.87	2	1849.74	2.31	3
Morinda citrifolia	102.02	1	102.02	0.13	8
Neisosperma oppositifolia	60.42	12	725.10	0.91	6
Pandanus tectorius	213.72	1	213.72	0.27	7
Pouteria obovata	91.56	1	91.56	0.11	9
Psychotria mariana	95.80	8	766.43	0.96	5
Terminalia catappa	720.98	2	1441.97	1.80	4
TR 14 All Plots (4)					
Barringtonia asiatica	1113.51	2	2227.02	2.78	2
Cocos nucifera	553.29	46	25451.53	31.81	1
Hibiscus tiliaceus	24.17	27	652.51	0.82	3
Morinda citrifolia	211.13	1	211.13	0.26	5
Terminalia catappa	547.11	1	547.11	0.68	4

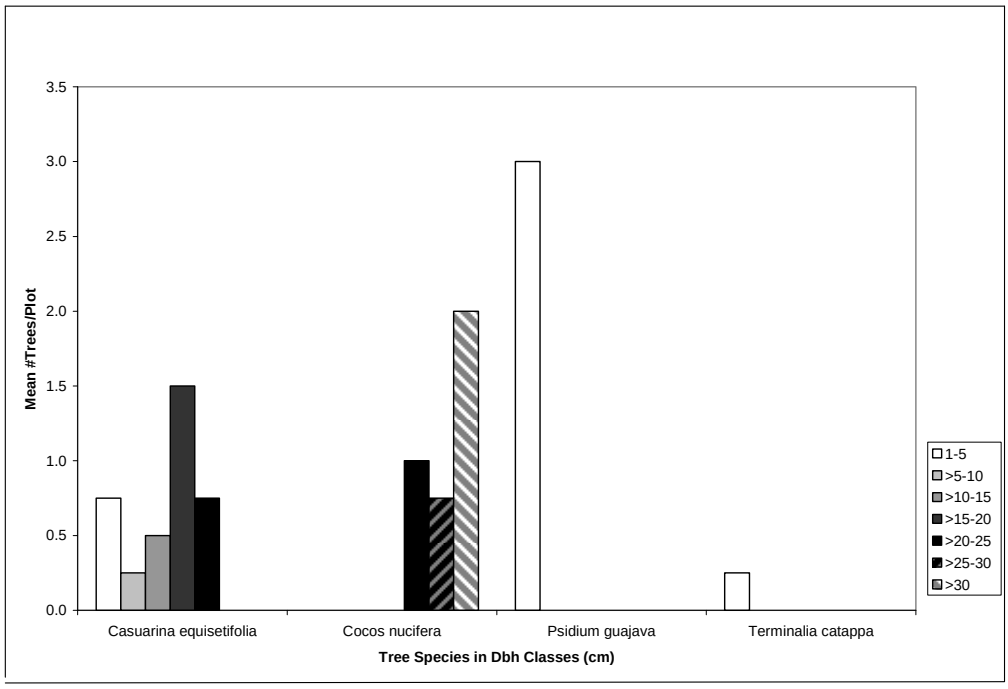

Figure 2. Size class distribution of tree species in coconut forest of transect 6 on the northwest side of Pagan.

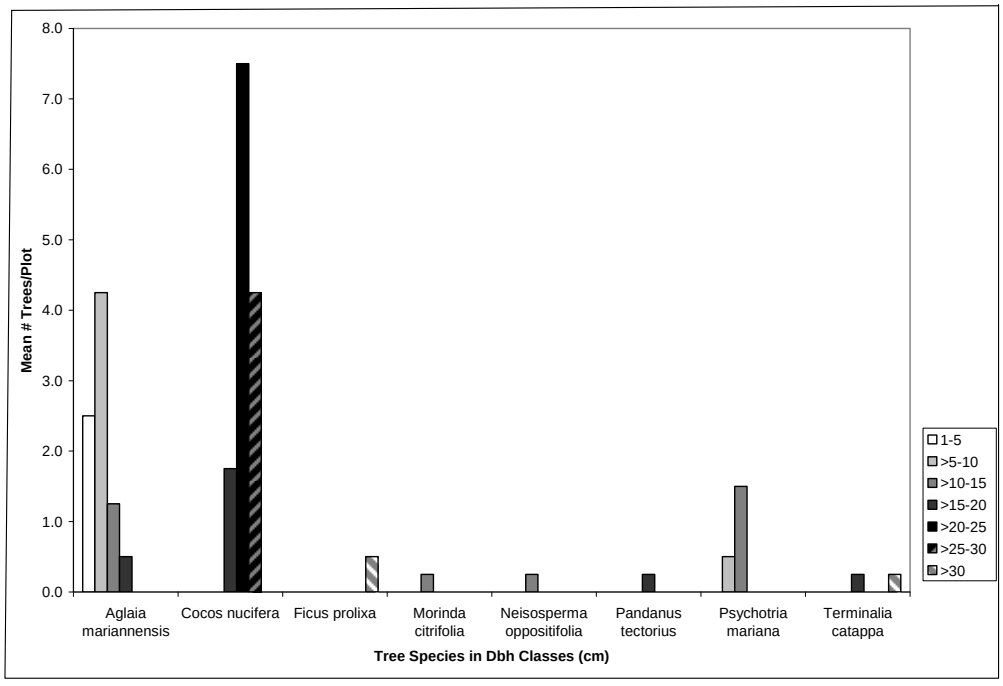

Figure 3. Size class distribution of tree species in coconut forest of transect 8 on the northeast side of Pagan.

Density of understory woody plants – Coconut forests of the northern section of the island had very few woody plants <2 m in height in the understory (Table 2). Most often seen were sprouting coconuts <1 m tall, which ranged from a mean of 21.5 per 100 m^2/plot on transect 8 to 2.5/plot on transect 14. The native trees *Morinda citrifolia* and *Terminalia catappa* were seen at low densities on 4 of the 5 transects. The common understory trees *Aglaia mariannensis*, *Neisosperma oppositifolia* (*fago*), and *Psychotria mariana* were seen at moderate mean densities on 2 to 3 transects, while others were restricted to single transects.

Transect 8 displayed the greatest species diversity of native seedlings and saplings in the sampled coconut forests. Nine species of native trees were represented in the <2 m understory of transect 8, and 2 of these trees (*Neisosperma oppositifolia* and *Pouteria obovata*, or *lalaha*) had mean densities >10 seedlings/100 m^2 plot. The only alien woody plant commonly seen was *Psidium guajava* (common guava), which occurred at high densities in the understory of transect 6 and was rare on transect 8.

Ground cover – Four of the five transects in coconut forest of the northern part of the island had relatively low percentage ground cover of plants; only transect 6 had live plants comprising more than a third of ground cover (Table 3). Most of the plots had litter-dominated ground cover, ranging from 48 to 67% of the ground cover sample. Coconut husks contributed an additional 2.1-9.3% of ground cover. Bare ground with no plants or litter was also high in the coconut forest, ranging from 13.4 to 24.8% of the sampled plots. Tree species were not well represented in ground cover of the coconut forest, except for *Psidium guajava*, which had 15.6% cover on transect 6 in the northwest. Coconut sprouts had measurable cover on all transects with the greatest amount, 2.5%, on transect 3 of the southwest. Only the native tees *Aglaia mariannensis* and *Hibiscus tiliaceus* had total cover >1% on the coconut forest transects; this cover was composed of lower branches, seedlings, and saplings.

Table 2. Mean Number/100 m^2 Plot of Woody Plant Species <2 m in Height along Transects in Coconut Forest on Northern Pagan.

Transect	TR 3	TR 3	TR 6	TR 6	TR 7	TR 7	TR 8	TR 8	TR 14	TR 14
Height	0.1-1.0m	>1-2m	0.1-1.0m	>1-2m	0.1-1.0m	>1-2m	0.1-1.0m	>1-2m	0.1-1.0m	>1-2m
Aglaia mariannensis	1.5	0					8.3	0.5	0.6	0.3
Barringtonia asiatica					7.0	0				
Clerodendrum buchananii									0.3	0.3
Cocos nucifera	19.0	0	5.1	0.8	5.1	0	21.5	0	2.5	0
Erythrina variegata	3.0	0								
Eugenia palumbis							0.3	0		
Ficus tinctoria	0.3	0								
Hibiscus tiliaceus					0.5	0				
Melanolepis multiglandulosa	0.3	0					0.3	0		
Morinda citrifolia			0.3	0.3	4.8	0	7.3	0	1.3	0
Neisosperma oppositifolia					0.5	0	11.1	1		
Ochrosia mariannensis							0	0.3		
Pouteria obovata							16.3	0		
Premna serratifolia							0.5	0		
Psidium guajava			30.8	17.5			0	0.3		
Psychotria mariana					1.5	0.5	4.0	0		
Sida acuta	0.3	0								
Terminalia catappa	0.3	0	0.3	0	0.5	0	0.3	0		

Table 3. Ground Cover (%) in Pooled Plots of Transects in Coconut Forest on Northern Pagan.

	TR 3	TR 6	TR 7	TR 8	TR 14
Tree Species	**%Cover**	**%Cover**	**%Cover**	**%Cover**	**%Cover**
Aglaia mariannensis	0.01			1.88	0.03
Barringtonia asiatica			0.13		0.50
Casuarina equisetifolia		0.50	0.01		
Cocos nucifera	2.63	0.04	0.15	1.53	1.01
Erythrina variegata	0.14				
Ficus prolixa				1.00	
Ficus tinctoria	0.01				
Hibiscus tiliaceus	0.38		5.43	0.01	1.50
Melanopsis multiglandulosa				0.01	
Morinda citrifolia	0.01		0.14	0.04	0.01
Neisosperma oppositifolia			0.01	0.28	
Pouteria obovata				0.03	
Premna serratifolia				0.01	
Psidium guajava		15.63			
Psychotria mariana			0.03	0.89	0.00
Terminalia catappa	0.01	0.25	0.03	0.14	
Low Shrubs and Forbs					
Alysicarpus vaginalis		0.13			0.01
Capsicum frutescens				0.01	
Chamaesyce hirta					0.03
Chamaesyce prostrata	0.01				
Chamaesyce thymifolia		0.03			0.01
Chromolaena odorata	8.13	0.38			
Clerodendrum buchananii					0.01
Crotalaria pallida					0.01
Cyanthillium cinereum	0.01	0.04			0.04
Desmodium incanum	2.13				
Desmodium triflorum	0.01	0.01			0.01
Emilia sonchifolia		0.01		0.01	0.01
Hedyotis corymbosa		0.01			0.03
Operculina ventricosa					0.01
Phyllanthus amarus	0.40	0.16		0.06	0.16
Senna obtusifolia	0.03				0.01
Sida acuta	0.28				0.01
Stachytarpheta jamaicensis	0.01				
Urena lobata/Triumfetta semitriloba	0.03				0.01
Sedges and Grasses					
Chloris barbata		0.01			
Chrysopogon aciculatus	1.13	0.64			0.13
Cynodon dactylon		0.13			
Cyperus compressus					0.16
Cyperus cyperinus					0.03

Table 3 (continued)	TR 3	TR 6	TR 7	TR 8	TR 14
Cyperus javanicus		0.04	0.01	0.01	0.03
Cyperus polystachyos		0.78	0.01	0.01	
Cyperus spp.	0.01				
Dactylotenium aegyptium		0.01			
Digitaria spp.	1.63	0.75		0.16	0.03
Fimbristylis cymosa		0.64			0.01
Fimbristylis dichotoma	0.01	0.00	0.01	0.28	0.38
Scleria lithosperma					0.01
Sporobolus fertilis		0.39			
Sporobolus sp.			0.01		
Ferns					
Nephrolepis hirsutula	0.03	16.25	13.25	2.13	0.01
Phymatosorus scolopendria	0.01		0.01	0.01	0.01
Pityrogramma calomelanos		0.03			
Pteris quadriaurita	0.41	0.13	0.04	3.01	0.01
Pteris vittata		0.01			
All Plants	17.44	36.96	19.23	11.5	4.23
Bare	14.63	13.38	13.38	17.38	24.75
Litter	59.25	47.88	53.50	66.88	61.75
Coconut husk	5.50	2.13	13.63	3.75	9.25
Rock	3.50	0.00	0.50	0.9	0.50

Ground cover of small shrubs and forbs was very low in the northern coconut forest, except for the alien plants *Chromolaena odorata* (*masigsig* or Siam weed) and *Desmodium incanum* (beggarweed) on transect 3 in the southwest. All other species of shrubs and forbs had less than 1% cover, and they were typically present in only trace amounts in the ground cover. Sedges and grasses also had little cover in the coconut forest; only the indigenous stoloniferous grasses *Chrysopogon aciculatus* (golden beardgrass) and *Digitaria* spp. (crabgrass) had >1% cover on any transect in this vegetation type. Two native ferns were found in the ground cover of plots of all coconut forest transects of the northern part of the island. The indigenous swordfern *Nephrolepis hirsutula* had high cover on both transects 6 and 7 of the north and northwest, and *Pteris quadriaurita*, a Micronesian endemic fern, occurred with low cover except on transect 8 of the northeast, where its cover was 3.0%.

Coconut Forest of Southern Pagan

Two transects were used to sample coconut forest on the southern part of the island. Transect 10 went through a coconut plantation on the coastal shelf of the southwestern region, and transect 11 was at the base of a cliff on a central plateau near the southern tip of the island (Fig. 1).

Tree density, basal area, and dominance – *Cocos nucifera* was the dominant tree of transects 10 and 11, based on tree density and mean basal area (Table 4). The second-ranked species of transect 10 was the native coastal fish poison tree *Barringtonia asiatica*, which often has increased density in areas of former human habitation. The second-ranked tree of the higher-elevation transect 11 was the common native understory tree *Aglaia mariannensis*, which had low mean basal area but high numbers in plots. The native tree *Elaeocarpus joga* (*yoga*) was the third-most dominant species of transect 11; even though only a single tree occurred in plots, its size was large. Six other native tree species were found in plots of transect 11.

Density of understory woody plants – Coconut forests of the southern part of the island were similar to those of the northern section with very few woody plants <2 m in height in the understory (Table 5). The lower-elevation transect 10 had only sprouting coconuts, seedlings of the co-dominant *Barringtonia asiatica* and a few *Psychotria mariana* seedlings in the understory. Low-stature woody plants were more diverse in plots of transect 11 on the upper plateau. The common native trees *Aglaia mariannensis* and *Morinda citrifolia* had mean plot densities of 5.0-6.0 seedlings along transect 11, and lesser amounts of 3 other tree species were also seen. The only alien woody species counted in plots of transect 11 was *Urena lobata*, present in very low numbers.

Table 4. Density, Mean Basal Area, and Dominance of Tree Species in Plots (800m^2/transect) of Coconut Forest on Southern Pagan.

Transect/Species	MeanBA (cm^2)	#trees	Dominance ($cm^2/800m^2$)	Dominance (m^2/ha)	Rank
TR 10 All Plots (4)					
Aglaia mariannensis	56.99	4	227.96	0.28	6
Artocarpus altilis	1200.12	1	1200.12	1.50	4
Barringtonia asiatica	832.65	8	6661.17	8.33	2
Casuarina equisetifolia	310.23	16	4963.70	6.20	3
Cocos nucifera	531.80	31	16485.68	20.61	1
Ficus tinctoria	342.90	1	342.90	0.43	5
Hibiscus tiliaceus	16.17	7	113.17	0.14	8
Psychotria mariana	37.76	5	188.79	0.24	7
TR 11 All Plots (4)					
Aglaia mariannensis	55.96	59	3301.86	4.13	2
Cocos nucifera	508.56	42	21359.72	26.70	1
Elaeocarpus joga	1306.74	1	1306.74	1.63	3
Ficus tinctoria	125.01	2	250.02	0.31	7
Melanolepis multiglandulosa	109.30	1	109.30	0.14	8
Morinda citrifolia	115.04	3	345.13	0.43	6
Neisosperma oppositifolia	149.28	4	597.12	0.75	5
Pandanus tectorius	70.85	1	70.85	0.09	9
Psychotria mariana	112.60	7	788.17	0.99	4

Table 5. Mean Number/100 m^2 Plot of Woody Plant Species <2 m in Height along Transects in Coconut Forest on Southern Pagan.

Transect	TR10	TR 10	TR 11	TR 11
Height	0.1-1.0m	>1-2m	0.1-1.0m	>1-2m
Aglaia mariannensis			5.0	0
Barringtonia asiatica	2.0	0		
Cocos nucifera	4.8	0	1.8	0
Guamia mariannae			1.0	0
Melanolepis multiglandulosa			1.3	0
Morinda citrifolia			6.0	0
Psychotria mariana	0.5	0	1.8	0
Urena lobata/*Triumfetta semitriloba*			0.3	0

Ground Cover – The coconut forests of transect 10 had very low cover of plants (9.3%) with only coconut sprouts, *Barringtonia asiatica* seedlings, the apparently native bunchgrass *Garnotia stricta*, and moss each achieving greater than 1% cover in the pooled plots (Table 6). Seedlings of 5 native tree species and several native sedges and grasses had almost no measurable cover. Most of the ground was covered by litter (55.0%) and rock (8.9%), and more than a quarter of the area of plots was bare of any plant or litter cover.

Transect 11 on the upper plateau had a similar high cover of litter (54.1%), but less bare ground was exposed (11.8%), and more plant cover was seen (21.7%) than on transect 10 (Table 6). Plants with the greatest cover on transect 11 were the native ferns *Nephrolepis hirsutula* and *Pteris quadriaurita*, the indigenous grass *Garnotia stricta*, a grass of uncertain status (*Sporobolus* sp.), the weedy composite *Chromolaena odorata*, and coconut sprouts. All other plants seen had less than 1% ground cover in plots. Most of the plant species (13) that occurred in trace amounts on transect 11 were alien herbaceous plants (forbs) and low shrubs, but native sedges and grasses, the woody vine *Jasminum marianum* (*banago*), and the epiphytic fern *Davallia solida* (*pagua-machena*) were also seen. Although present with very low cover, seedlings of 5 native tree species were also noted in the ground cover of plots of this transect.

Mixed Native and Alien Forest of Northern Pagan

Two transects were placed in partly native forest of the southern slope of the northern half of Pagan. Transect 1 followed the base of the old caldera wall that stretched east to west on the island, this transect was positioned between the cliff face and the main road to the south from the old village site and main camp. Transect 2 was east of transect 1 and followed a low, rocky lava ridge that curved around a small hill (Fig. 1). These areas were among the few forest

Table 6. Ground Cover (%) in Pooled Plots of Transects in Coconut Forest on Southern Pagan.

	TR 10	TR 11		TR 10	TR 11
Tree Species	**%Cover**	**%Cover**	**Sedges and Grasses**	**%Cover**	**%Cover**
Aglaia mariannensis	0.01	0.88	*Chrysopogon aciculatus*	0.65	0.14
Barringtonia asiatica	2.00		*Cyperus cyperinus*		0.39
Casuarina equisetifolia	0.13		*Cyperus javanicus*	0.01	0.14
Cocos nucifera	1.13	1.75	*Cyperus* spp.	0.14	
Guamia mariannae		0.50	*Digitaria* spp.	0.01	0.88
Hibiscus tiliaceus	0.13		*Fimbristylis dichotoma*	0.01	
Melanopsis multiglandulosa	0.01		*Garnotia stricta*	1.88	1.00
Morinda citrifolia		0.38	*Miscanthus floridulus*		0.50
Pandanus tectorius		0.13	*Scleria lithosperma*	0.01	
Psychotria mariana	0.01	0.38	*Sporobolus* sp.		1.38
Low Shrubs and Forbs			**Ferns and Moss**		
Abrus precatorius		0.01	*Davallia solida*	0.01	0.03
Amaranthus viridus		0.01	Moss	2.38	
Chromolaena odorata		1.01	*Nephrolepis hirsutula*		6.00
Commelina benghalensis		0.14	*Phymatosorus scolopendria*	0.01	
Cyanthillium cinereum		0.15	*Psilotum nudum*	0.01	
Desmodium triflorum		0.01	*Pteris quadriaurita*	0.76	5.38
Elephantopus mollis		0.01			
Emilia sonchifolia		0.01	**All Plants**	9.33	21.71
Hedyotis corymbosa		0.01	Bare	25.63	11.75
Jasminum marianum		0.03	Litter	55.00	54.13
Operculina ventricosa	0.01	0.05	Coconut husk	1.38	1.88
Oxalis corniculata		0.03	Rock	8.88	10.88
Phyllanthus amarus		0.03			
Piper betle		0.14			
Urena lobata/Triumfetta semitriloba		0.26			
Xanthosoma sagittifolium	0.01				

patches of the southern half of northern Pagan that were not covered by coconut groves or *Casuarina equisetifolia*.

Tree density, basal area, and dominance – The dominant tree of transect 1 was *Cocos nucifera*, coconut, but 2 other alien tree species, *Jatropha curcas* (physic nut) and *Leucaena leucocephala* (*tangantangan*) were not far below coconut in dominance rank, based on number of trees and mean basal area

(Table 7). The forest was patchy with dense stands of *Jatropha* and *Leucaena* mixed with scattered individuals of 7 native tree and shrub species, as well as the alien *Psidium guajava*. Size class distribution of the tree species in forest plots of transect 1 showed that only *Jatropha, Leucaena*, and the natives *Aglaia mariannensis* and *Ochrosia mariannensis* (lipstick tree) had multiple size classes including trees of small diameter (Fig. 4). The 2 alien trees appeared to have increasing populations, with relatively high mean numbers of trees in the lower

Table 7. Density, Mean Basal Area, and Dominance of Tree Species in Plots (800m^2/transect) of Mixed Native and Alien Forest on Northern Pagan.

Transect/Species	MeanBA (cm^2)	#trees	Dominance (cm^2/800m^2)	Dominance (m^2/ha)	Rank
TR 1 All Plots (4)					
Aglaia mariannensis	57.04	8	456.32	0.57	6
Clerodendrum inerme	1.77	1	1.77	0.00	10
Cocos nucifera	603.88	8	4831.04	6.04	1
Eugenia palumbis	1.77	1	1.77	0.00	10
Jatropha curcas	33.65	95	3196.75	4.00	2
Leucaena leucocephala	39.90	66	2633.40	3.29	3
Morinda citrifolia	105.63	1	105.63	0.13	8
Ochrosia mariannensis	40.06	4	160.24	0.20	7
Psidium guajava	5.54	7	38.78	0.05	9
Psychotria mariana	156.59	4	626.36	0.78	5
Terminalia catappa	338.15	2	676.30	0.85	4
TR 2 All Plots (4)					
Aglaia mariannensis	62.70	14	877.79	1.10	7
Cocos nucifera	497.90	6	2987.40	3.73	1
Erythrina variegata	1040.09	1	1040.09	1.30	6
Eugenia palumbis	6.60	1	6.60	0.01	13
Ficus prolixa	379.89	2	759.78	0.95	8
Ficus tinctoria	194.03	8	1552.24	1.94	5
Grewia crenata	122.66	1	122.66	0.15	12
Neisosperma oppositifolia	175.59	15	2633.85	3.29	2
Ochrosia mariannensis	136.15	18	2450.70	3.06	3
Pandanus tectorius	203.48	1	203.48	0.25	11
Pouteria obovata	238.07	8	1904.56	2.38	4
Psychotria mariana	44.91	15	673.65	0.84	9
Terminalia catappa	555.43	1	555.43	0.69	10

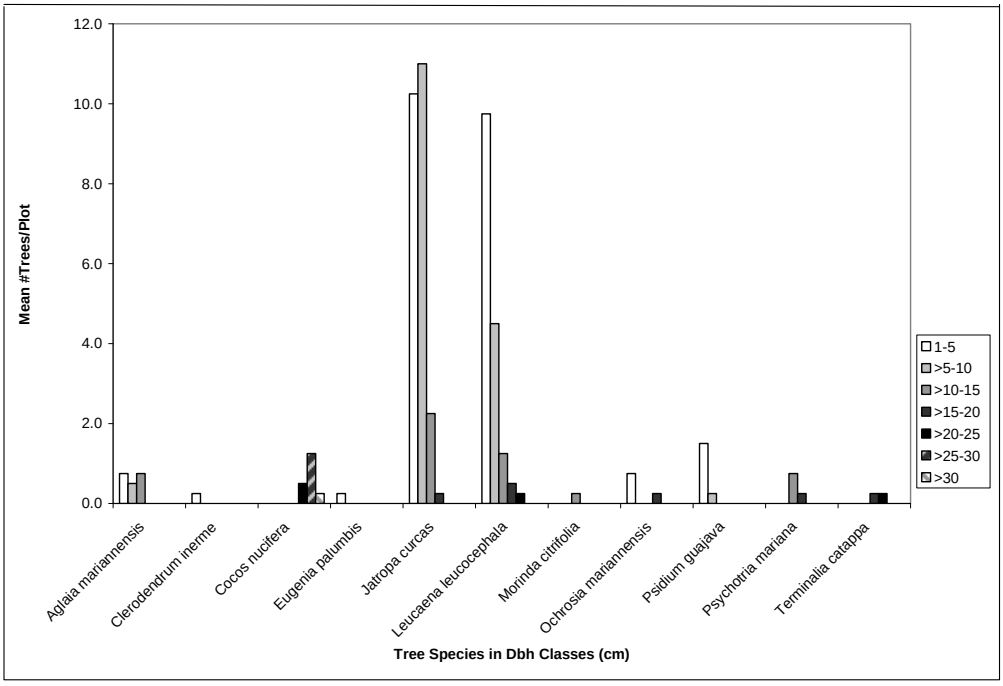

Figure 4. Size class distribution of tree species in mixed native and alien forest of transect 1 on the southeast side of northern Pagan.

diameter classes and few large trees per plot. The mean number of trees per plot was very low for *Aglaia* and *Ochrosia* and 5 other native trees and shrubs.

Transect 2 forests had a high diversity of native trees with 12 species sampled in vegetation plots, in addition to *Cocos nucifera*. Although coconut was the dominant species because of its high mean basal area, 2 native species were not far behind in dominance rank (Table 7). Both *Neisoperma oppositifolia* and *Ochrosia mariannensis* had relatively high densities in the plots of transect 2, but their mean basal diameters were far lower than those of coconut. *Pouteria obovata* and the fig *Ficus tinctoria* (*hodda*) were also well represented in plots of this forest. *Aglaia mariannensis* and *Psychotia mariana* had relatively high plot densities but small mean basal diameters.

Although mean numbers of trees/plot were low, multiple size classes were present in the stand structure of several native tree species in the forests of

transect 2 (Fig. 5). For both *Neisosperma* and *Ochrosia*, trees of 5 diameter classes ranging from small trees to those >20 cm dbh were found in vegetation plots of the transect. *Pouteria obovata* stand structure appeared less stable with only trees with >10 cm diameter counted. By contrast, *Psychotria mariana* and *Aglaia mariannensis* had relatively high mean numbers of small trees, but none with diameters >15 cm.

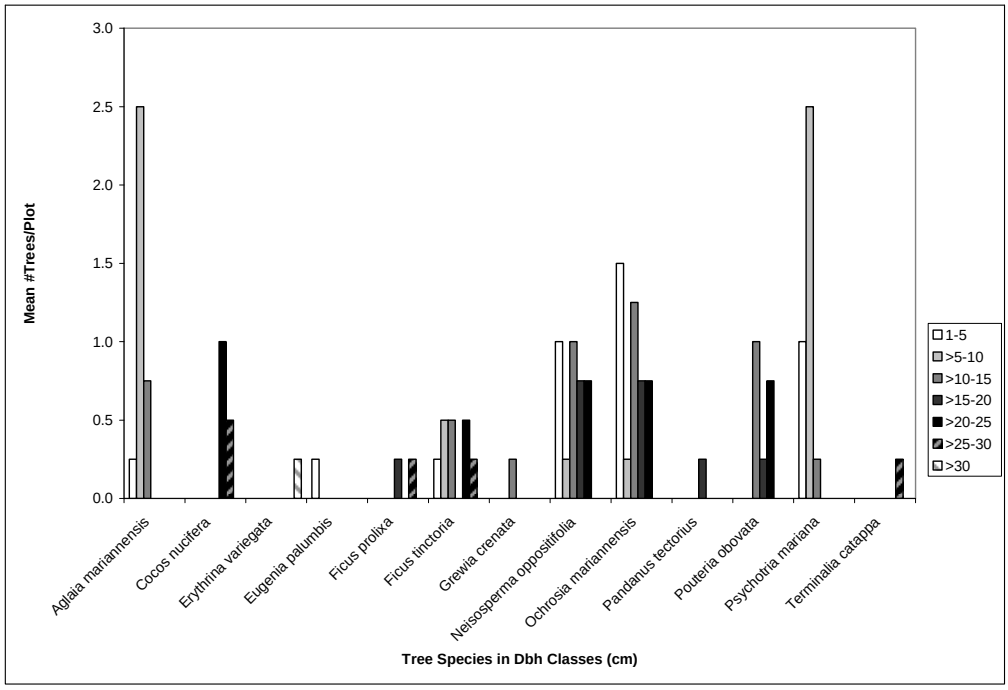

Figure 5. Size class distribution of tree species in mixed native and alien forest of transect 2 on the southeast side of northern Pagan.

Density of understory woody plants – The understory of forest plots along transect 1 was very open with a mixture of native and alien plant seedlings and saplings. The most abundant woody species on average was the alien tree *Leucaena leucocephala* with more than 20 individuals/100 m^2 with height <2 m (Table 8). The most common native tree seedlings were those of *Aglaia mariannensis*, with a mean of 4.6 (combined for the size classes) in plots of the

Table 8. Mean Number/100 m^2 Plot of Woody Plant Species <2 m in Height along Transects in Mixed Native and Alien Forest on Northern Pagan.

Transect	TR 1	TR 1	TR 2	TR 2
Height	0.1-1.0m	>1-2m	0.1-1.0m	>1-2m
Aglaia mariannensis	4.3	0.3	47.3	0.8
Capsicum frutescens			0.3	0
Clerodendrum buchananii	0.8	0	11.8	0.8
Clerodendrum inerme	1.3	0.3		
Cocos nucifera	3.8	1.3		
Erythrina variegata	2.5	0.3	8.3	0
Eugenia palumbis	1.0	0	1.8	0.8
Ficus prolixa	0.3	0		
Ficus tinctoria	0.3	0	0.8	0
Jatropha curcas	1.8	0.8		
Leucaena leucocephala	14.8	6.8	0.3	0
Melanolepis multiglandulosa			0.3	0
Morinda citrifolia	1.3	0.3	6.5	0.3
Neisosperma oppositifolia			16.8	0.8
Ochrosia mariannensis	1.3	1.0	12.5	1.3
Pouteria obovata			0.8	0.3
Psidium guajava	1.3	1.8	0.3	0
Psychotria mariana	0.5	0	11.0	0.8
Terminalia catappa	0.5	0	0.5	0
Urena lobata/Triumfetta semitriloba	2.0	0	13.8	0

transect. Seedlings of the native coral tree *Erythrina variegata* had a mean density of 2.5/100 m^2, and 9 other native shrubs and tree seedlings and saplings were present in lesser amounts. As expected from the prevalence of non-natives in the tree composition in the forest, sprouting coconuts and seedlings and saplings of *Jatropha curcas* and *Psidium guajava* were present in the understory of transect 1 forest, as was the alien shrub *Urena lobata*.

The understory of native forest of transect 2 supported a higher density of native tree seedlings and saplings than did that of transect 1. The mean number of young *Aglaia mariannensis* counted in transect 2 plots was more than 10 times greater than that of transect 1, with 48.1/100 m^2 observed (Table 8).

Seedlings of the native shrub *Clerodendrum buchananii* and native trees, such as *Erythrina variegata, Neisosperma oppositifolia*, *Ochrosia mariannensis*, and *Psychotria mariana*, were seen at densities >8/100 m^2, and seedlings and saplings of 6 additional native tree species were also found in plots of transect 2. The most abundant alien woody plants in transect 2 forests were *Urena lobata* (aramina) and/or *Triumfetta semitriloba* (Sacramento bur), which were not always distinguished from one another.

Ground cover – Ground cover of vegetation plots of transect 1 was composed mostly of litter and rock, and 23.4% of the plots was bare soil (Table 9). Almost a quarter of the pooled plots (24.7%) had plant cover on the ground, but most of this was composed of alien plants. Alien plants with the greatest ground cover on transect 1 were the shrub *Chromolaena odorata*, seedlings of tree species *Leucaena leucocephala* and *Jatropha curcas*, and the creeping carpetgrass *Axonopus compressus*. Among native plants only the sprawling shrub *Clerodendrum inerme* had more than 2% cover. Native tree seedlings, as well as native sedges and ferns were present with very low measured ground cover.

Plots of transect 2 also had large amounts of litter and rock as ground cover, as well as 11.1% bare ground, but the 22.8% total plant cover was composed mostly of native species (Table 9). Plants with the most measured cover in pooled plots were the native sedge *Scleria lithosperma*, the native shrub *Clerodendrum buchananii*, and seedlings/saplings of native tree species *Aglaia mariannensis*, *Ficus* spp., *Neisosperma oppositifolia*, *Ochrosia mariannensis*, and *Psychotria mariana*. Six other native woody plants, as well as native sedges, ferns, and *Digitaria* spp. crabgrass were present in plots with <1% cover each. Among alien plant species of transect 2, only coconut sprouts had cover >1%, but 3 alien tree species, 12 herbaceous or shrub species, and 2 species of creeping non-native grasses occurred in trace amounts.

Table 9. Ground Cover (%) in Pooled Plots of Transects in Mixed Native and Alien Forest on Northern Pagan.

Tree Species	TR 1	TR 2	Sedges and Grasses	TR 1	TR 2
Aglaia mariannensis	0.38	2.63	*Axonopus compressus*	1.25	0.75
Bauhinia monandra		0.01	*Chrysopogon aciculatus*	0.03	
Carica papaya	0.01	0.03	*Cynodon dactylon*		0.13
Cocos nucifera	0.14	1.64	*Cyperus javanicus*	0.01	0.14
Erythrina variegata	0.03	0.01	*Cyperus* spp.	0.15	0.26
Eugenia palumbis	0.13	0.38	*Digitaria* spp.	0.03	0.63
Ficus prolixa		1.75	*Fimbristylis cymosa*		0.13
Ficus tinctoria	0.01	1.25	*Fimbristylis* spp.	0.03	0.13
Jatropha curcas	1.63		*Scleria lithosperma*		2.26
Leucaena leucocephala	2.26	0.13	**Ferns**		
Melanopsis multiglandulosa	0.39	0.01	*Cheilanthes tenuifolia*		0.01
Morinda citrifolia	0.13	0.01	*Davallia solida*	0.28	0.01
Neisosperma oppositifolia		1.63	*Nephrolepis hirsutula*	0.66	0.39
Ochrosia mariannensis	0.14	1.15	*Phymatosorus scolopendria*	0.03	0.14
Pouteria obovata		0.38	*Pteris quadriaurita*	0.65	
Psidium guajava	0.39		*Pteris vittata*	0.01	
Psychotria mariana		1.53	**All Plants**	24.68	22.79
Terminalia catappa			Bare	23.38	11.13
Shrubs, Vines, and Forbs			Coconut Husk	4.00	
Abrus precatorius		0.63	Litter	33.13	36.50
Achyranthes aspera	0.13		Rock	15.25	30.00
Alysicarpus vaginalis	0.01	0.13			
Atylosia scarabaeoides	0.13	0.01			
Blechum pyramidatum	0.63				
Capsicum frutescens	0.14	0.01			
Chamaesyce prostrata		0.01			
Chromolaena odorata	10.64	0.01			
Clerodendrum buchananii	0.01	1.39			
Clerodendrum inerme	2.50				
Cyanthillium cinereum	0.15	0.04			
Desmodium incanum	0.51				
Desmodium triflorum	0.03				
Emilia sonchifolia	0.03	0.01			
Jasminum marianum		0.15			
Jatropha gossypifolia	0.01				
Phyllanthus amarus	0.04	0.01			
Portulaca pilosa		0.01			
Senna obtusifolia	0.01				
Sida acuta		0.01			
Stachytarpheta jamaicensis		0.01			
Urena lobata/Triumfetta semitriloba	0.50	0.50			
Unknown seedling	0.50				

Mixed Native Forest of Southern Pagan

Two transects and supplemental plots were used to sample the mixed native forest of the rugged southern part of the island (Fig. 1). Transect 9 ran south to north on the lower shelf of the southwestern slope of the island. Transect 9 supplemental was composed of 3 additional vegetation plots on the coastal shelf southwest of transect 9. Transect 11-north was on the upper plateau of southern Pagan upslope of transect 9 and north of the coconut forest sampled with transect 11.

Tree density, basal area, and dominance – The dominant tree of both transects and supplemental plots of southern Pagan mixed native forests was *Casuarina equisetifolia*, which had the largest mean basal area in all transects (Table 10). Vegetation plots of transect 9 on the lower shelf of the southern part of the island had many more trees of the second- and third-ranked dominant native species *Aglaia mariannensis* and *Psychotria mariana* than were counted for ironwood, but these trees were of smaller diameter and therefore had much smaller mean basal areas. The fig species *Ficus prolixa* and *F. tinctoria* had large mean basal areas, but few trees occurred in plots of transect 9. In total, 11 native tree species occurred in the sampled forest of transect 9, and no alien trees were seen. The supplemental plots near transect 9 supported only 5 native tree species with *Pouteria obovata* second in dominance after *Casuarina equisetifolia*.

Transect 11-north was similar in composition to the lower-elevation transect 9, but supported only 8 native tree species; again no alien trees were found in this forest. Second in dominance to ironwood was *Aglaia mariannensis*, with a high number of trees of small mean basal area (Table 10). Third and fourth in dominance were *Pouteria obovata and Psychotria mariana*.

Table 10. Density, Mean Basal Area, and Dominance of Tree Species in Plots (600-800m^2/transect) of Mixed Native Forest on Southern Pagan.

Transect/Species	MeanBA (cm^2)	#trees	Dominance (cm^2/800m^2)	Dominance (m^2/ha)	Rank
TR 9 All Plots (4)					
Aglaia mariannensis	85.05	34	2891.83	3.61	2
Aidia cochinchinensis	23.75	1	23.75	0.03	10
Casuarina equisetifolia	632.40	10	6324.01	7.91	1
Colubrina asiatica	12.56	1	12.56	0.02	11
Ficus prolixa	484.76	2	969.52	1.21	5
Ficus tinctoria	351.19	3	1053.57	1.32	4
Geniostoma rupestre	76.26	2	152.52	0.19	8
Morinda citrifolia	35.53	8	284.20	0.36	7
Pouteria obovata	170.03	4	680.13	0.85	6
Premna serratifolia	56.72	1	56.72	0.07	9
Psychotria mariana	31.88	62	1976.73	2.47	3
TR 9 Supplement (3 Plots)			**Dominance (cm^2/600m^2)**		
Aglaia mariannensis	74.65	15	1119.76	1.87	3
Casuarina equisetifolia	532.52	17	9052.76	15.09	1
Ficus tinctoria	144.25	3	432.74	0.72	5
Pouteria obovata	256.37	10	2563.75	4.27	2
Psychotria mariana	60.81	11	668.88	1.12	4
TR 11-North All Plots (4)			**Dominance (cm^2/800m^2)**		
Aglaia mariannensis	67.32	56	3770.20	4.71	2
Casuarina equisetifolia	463.38	35	16218.40	20.27	1
Ficus tinctoria	91.96	4	367.84	0.46	7
Melanolepis multiglandulosa	76.03	2	152.05	0.19	8
Morinda citrifolia	76.44	7	535.08	0.67	5
Pouteria obovata	501.31	3	1503.92	1.88	3
Psychotria mariana	35.05	25	876.16	1.10	4
Terminalia catappa	171.11	3	513.34	0.64	6

Stand structure of the forest of transect 9 showed multiple diameter classes in the lower range with relatively high mean numbers of trees/plot for both *Aglaia mariannensis* and *Psychotria mariana* (Fig. 6). *Casuarina equisetifolia* trees occurred in 7 size classes, including an individual >50 cm in diameter, but mean numbers of trees were very low in each class, except for

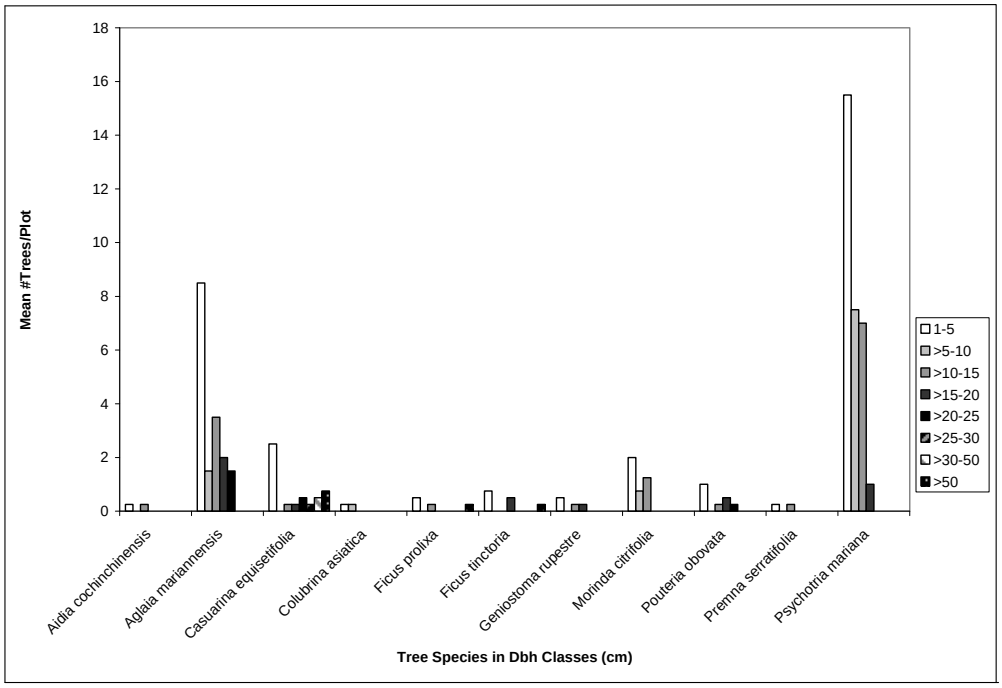

Figure 6. Size class distribution of tree species in mixed native forest of transect 9 on the southwest side of southern Pagan.

that of the smallest diameter of 1-5 cm. Five additional native species displayed stand structures with trees in 3-5 diameter classes, including that of the small trees 1-5 cm, but like *Casuarina equisetifolia*, mean numbers of trees in each class were very small.

The forest plots of transect 11-north on the upper plateau also had relatively high mean numbers of *Aglaia mariannensis* and *Psychotria mariana* in multiple size classes (Fig. 7). *Aglaia* trees were the most abundant of the natives, and this species appeared to have a relatively stable population with large mean numbers in the middle diameter classes and lower numbers of young trees and larger-diameter trees (Barbour *et al*. 1980). *Casuarina equisetifolia* also showed a stable population with low mean numbers of trees in 4 middle diameter classes and fewer trees in the smallest and largest diameter classes.

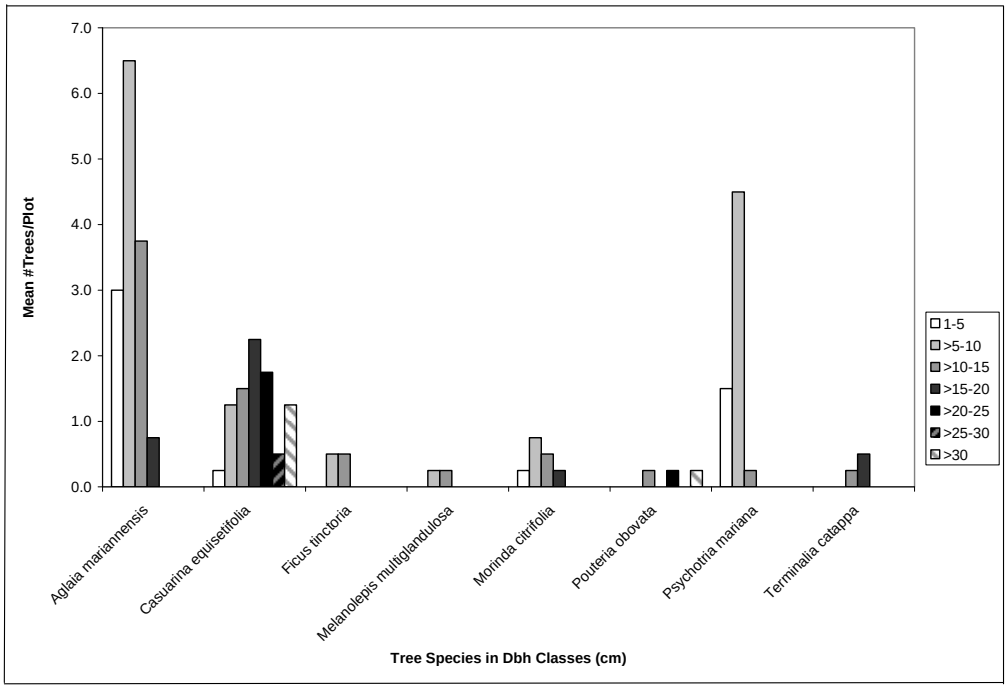

Figure 7. Size class distribution of tree species in mixed native forest of transect 11-north on the upper plateau of southern Pagan.

Density of understory woody plants – The understory of native forests of southern Pagan Island was very open with a low diversity of native tree species present as seedlings and saplings <2 m in height. Transect 9 on the lower shelf of the southwestern slope of the island had only 3 species of young trees in vegetation plots, with *Aglaia mariannensis* the most common with a mean of 4.5 individuals <1 m height and 2.0 >1 m tall (Table 11). Supplemental vegetation plots near transect 9 had 2 additional native woody plants in the understory and higher mean numbers of both *Aglaia mariannensis* and *Psychotria mariana* than did transect 9 plots. The native tree species *Psychotria* was present in the 3 supplemental plots in very large numbers with a mean of 220 seedlings per 100 m^2.

The forest sampled in plots of transect 11-north was somewhat more diverse than that of transect 9, with 7 native trees present as seedlings and

Table 11. Mean Number/100 m^2 Plot of Woody Plant Species <2 m in Height along Transects in Mixed Native Forest on Southern Pagan.

Transect	TR 9	TR 9	TR 9 Sup	TR 9 Sup	TR 11N	TR 11N
Height	0.1-1.0m	>1-2m	0.1-1.0m	>1-2m	0.1-1.0m	>1-2m
Aglaia mariannensis	4.5	2.0	14.6	1.7	81.0	1.0
Guamia mariannae					0.3	0
Jasminum marianum			0.7	0		
Melanolepis multiglandulosa					0.3	0
Morinda citrifolia	1.3	0	3.7	0	3.3	0
Pouteria obovata			0.3	0	1.8	0
Premna serratifolia					0.3	0
Psychotria mariana	2.3	1.5	220.0	0.0	8.3	1.0

saplings. *Aglaia mariannensis* had a high mean of 81.0 young trees 0.1-1.0 m in height, but a mean of 1.0 sapling >1-2 m tall in transect 11-north plots. *Psychotria mariana*, *Morinda citrifolia*, and *Pouteria obovata* seedlings and saplings were present with relatively low means, and a few seedlings of *Guamia mariannae*, *Melanolepis multiglandulosa*, and *Premna serratifolia* were also counted in plots of transect 11-north. No alien woody plants were seen in vegetation plots of either transect or supplemental plots of the forests of southern Pagan.

Ground Cover – Native grasses, ferns, and tree seedlings were the most prominent plants of the ground cover of native forests on the southern part of the island. Litter was the largest component of ground cover (43.3%) in transect 9 plots on the lower western slope of southern Pagan, and bare exposed soil covered 14.6% of the pooled plots (Table 12). However, live plants made up more than a third of the sampled ground cover (38.9%). The native swordferns *Nephrolepis biserrata* and *N. hirsutula* had the greatest percentage cover of any plants in transect 9 plots, and together comprised 26.8% of live plant cover. The native *Miscanthus floridulus* or swordgrass had 4.5% cover in pooled plots. Other plants relatively common in transect 9 plots were the native terrestrial fern

Table 12. Ground Cover (%) in Pooled Plots of Transects in Mixed Native Forest on Southern Pagan.

Tree Species	TR 9	TR 9 Sup	TR 11N
Aglaia mariannensis	0.63	5.67	0.63
Casuarina equisetifolia		0.83	0.89
Ficus prolixa	0.39		
Ficus tinctoria		0.02	0.63
Geniostoma rupestre	0.03		
Morinda citrifolia	0.01	0.02	0.39
Neisosperma oppositifolia		0.02	
Pandanus tectorius	0.39		
Pouteria obovata		0.67	0.01
Psychotria mariana	1.40	2.83	0.25
Terminalia catappa			0.01
Shrubs, Vines, and Forbs			
Abrus precatorius	0.01		
Chamaesyce hirta			0.01
Chromolaena odorata			0.01
Cyanthillium cinereum	0.01	0.17	0.01
Desmodium triflorum			0.01
Hedyotis corymbosa			0.01
Jasminum marianum	0.75		
Operculina ventricosa			0.13
Sedges and Grasses			
Chrysopogon aciculatus			0.01
Cyperus cyperinus			0.01
Cyperus javanicus			0.00
Garnotia stricta	1.88	0.52	1.15
Heteropogon contortus			7.00
Miscanthus floridulus	4.50		1.25
Scleria lithosperma	0.03		0.01
Ferns			
Cheilanthes tenuifolia			0.01
Davallia solida		0.01	0.03
Nephrolepis biserrata	11.00		
Nephrolepis hirsutula	15.75		8.38
Phymatosorus scolopendria			0.01
Pteris quadriaurita	2.14	2.18	0.03
All Plants	38.9	12.92	20.88
Bare	14.63	3.33	3.88
Litter	43.25	83.33	73.00
Rock	3.38	0.50	2.50

Pteris quadriaurita with 2.1% cover, a bunchgrass tentatively identified as *Garnotia stricta* with 1.9% cover, and seedlings of the native tree *Psychotria*

mariana with 1.4% cover. Seedlings of 6 other native trees and shrubs had cover <1% for each species. Only 2 alien forb and vine species were noted in trace amounts.

Supplemental plots near transect 9 were dominated by litter in the ground cover (83.3%) and had live plant cover of only 12.9% (Table 12). *Aglaia mariannensis* and *Psychotria mariana* seedlings made up most of the live plant in the ground cover with 5.7% and 2.8% cover, respectively. The native fern *Pteris quadriaurita* had cover of 2.2% in transect 9 supplemental plots. A few other plants had <1% cover each; these included seedlings of 5 native tree species, the indigenous grass *Garnotia stricta*, and the alien forb *Cyanthillium cinereum*, little ironweed.

Transect 11-north vegetation plots also had a very high cover of litter (73.0%), with 20.9% of the ground cover composed of live plants. Only 3.8% bare ground was measured in plots of this forest. Native grasses and ferns were prominent in transect 11-north plots. The native grasses *Heteropogon contortus* and *Miscanthus floridulus* had 7.0% and 1.3% cover, respectively, and the bunchgrass *Garnotia stricta* had 1.2% cover. The large swordfern *Nephrolepis hirsutula* had 8.4% cover in plots of transect 11-north. Other species had <1% cover each; these were primarily seedlings of 7 native trees, several native sedges and ferns, and 6 species of alien herbaceous plants.

Ironwood Forest of Northern Pagan

The ironwood forest was widespread on the northern part of the island and was sampled with 2 transects on the western and southwestern slopes of Mt. Pagan (Fig. 1). Transect 4 began near the old village site on the southwest flank of Mt. Pagan. Transect 5 was placed in forest on ridges north of Sanhiyong Lake and ended just west of the interior Sanhalom Lake.

Tree density, basal area, and dominance – The dominant tree of both transects of northern Pagan ironwood forest was *Casuarina equisetifolia*, which was almost the only tree observed in vegetation plots placed in these forests (Table 13). Other species that were seen sparingly in ironwood forests but did not occur as trees within sampled vegetation plots included the natives *Aglaia mariannensis*, *Erythrina variegata*, *Neisosperma oppositifolia*, *Pouteria obovata*, *Pandanus tectorius* (*kafu)*, *Ficus prolixa*, *F. tinctoria*, *Morinda citrifolia*, and *Premna serratifolia* (false elder). Alien trees and shrubs that were seen on the lower part of transect 4 were *Leucaena leucocephala*, *Psidium guajava*, *Senna obtusifolia* (*habucha*), and *Triphasia trifolia* (*limon de chine* or limeberry).

Table 13. Density, Mean Basal Area, and Dominance of Tree Species in Plots (800m^2/transect) of *Casuarina equisetifolia* Forest on Northern Pagan.

Transect/Species	MeanBA (cm^2)	#trees	Dominance (cm^2/800m^2)	Dominance (m^2/ha)	Rank
TR 4 All Plots (4)					
Casuarina equisetifolia	309.00	60	18539.96	23.17	1
Terminalia catappa	0.95	1	0.95	0.00	2
TR 5 All Plots (4)					
Casuarina equisetifolia	171.88	79	13578.47	16.97	1

The mean basal area of ironwood trees in these 2 northern Pagan transects was considerably smaller than that observed for ironwood trees in the mixed native forests of the southern part of the island, indicating that trees of transects 4 and 5 were relatively young. Stand structure of the dominant tree of northern ironwood forests indicated relatively low mean densities of ironwood in vegetation plots of both transects with trees in the middle diameter classes from >5-10 to >20-25 cm best represented and fewer trees in the smallest and largest classes (Fig. 8, Fig. 9).

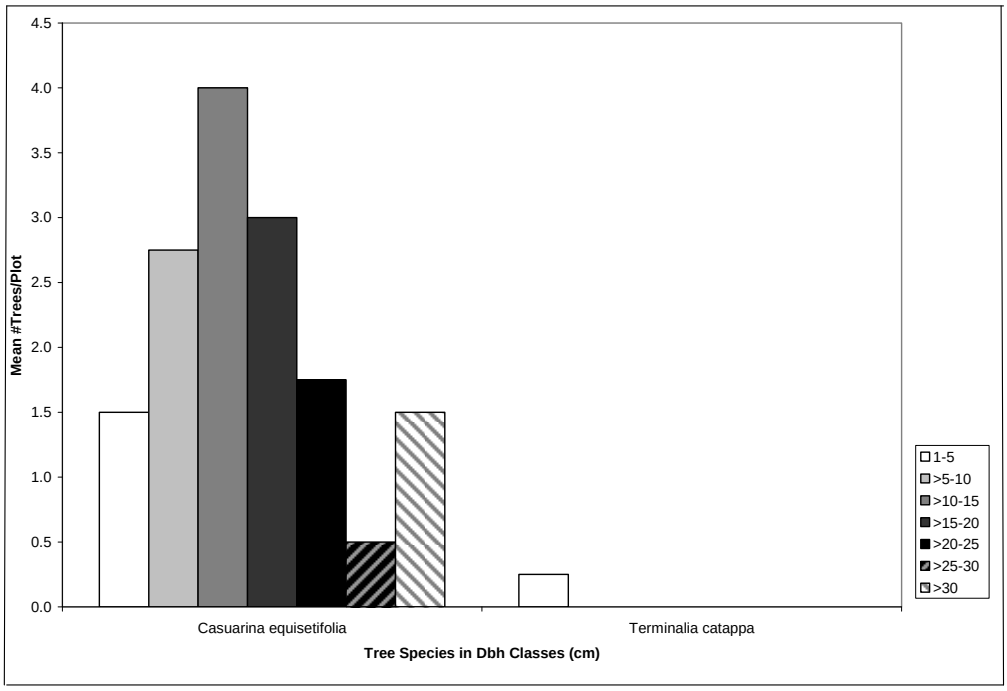

Figure 8. Size class distribution of tree species in *Casuarina equisetifolia* forest of transect 4 on the southwest side of northern Pagan.

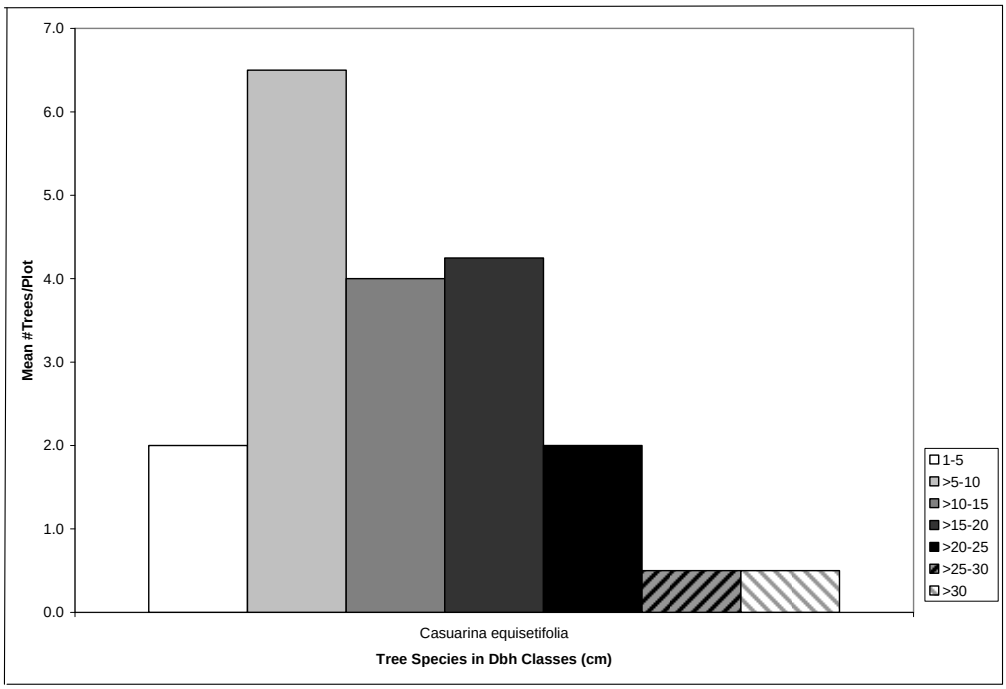

Figure 9. Size class distribution of *Casuarina equisetifolia* in forest of transect 5, on the west side of northern Pagan.

Density of understory woody plants – Very few woody plants were seen in the understory of ironwood forests of the North Island. Although it was the dominant species of these forests, *Casuarina equisetifolia* did not seem to be recruiting seedlings or saplings, as the mean density of ironwood < 2 m in height was extremely low in sampled vegetation of transects 4 and 5 (Table 14). The alien woody species *Psidium guajava* and a mix of *Urena lobata* and *Triumfetta semitriloba* had the highest mean densities observed in vegetation plots of the ironwood forest. Four species of native trees and the alien shrub *Triphasia trifolia* were observed at very low mean densities in the understory.

Table 14. Mean Number/100 m^2 Plot of Woody Plant Species <2 m in Height along Transects in *Casuarina equisetifolia* Forest on Northern Pagan.

Transect		TR 4	TR 4	TR 5	TR 5
Height		0.1-1.0m	>1-2m	0.1-1.0m	>1-2m
Casuarina equisetifolia		0	0.3		
Ficus tinctoria		0.3	0		
Melanolepis multiglandulosa		0.3	0		
Morinda citrifolia		0.5	0		
Pouteria obovata		0.3	0		
Premna serratifolia				0.3	0
Psidium guajava				1.3	0
Urena lobata/Triumfetta semitriloba		6.1	0		
Triphasia trifolia		0.5	0		

Ground cover – Litter was the largest single component of ground cover on both transects in the ironwood forest, but transect 4 also had greater than 50% of the vegetation plots covered with live plants (Table 15). The dominant ground cover species of transect 4 were the native swordfern *Nephrolepis hirsutula* with 25.6 % cover and the alien shrub *Chromolaena odorata* (15.9%).

Table 15. Ground Cover (%) in Pooled Plots of Transects in *Casuarina equisetifolia* Forest on Northern Pagan.

Tree Species	TR 4	TR 5	Sedges and Grasses	TR 4	TR 5
Casuarina equisetifolia	0.50	0.26	*Axonopus compressus*	0.39	
Ficus tinctoria	0.01		*Chrysopogon aciculatus*	0.25	
Melanolepis multiglandulosa	0.01		*Cyperus compressus*	0.14	
Premna serratifolia		0.13	*Cyperus cyperinus*		0.39
Psidium guajava		0.14	*Cyperus javanicus*	0.01	
Terminalia catappa	0.01		*Digitaria* spp.	2.64	1.38
Shrubs, Vines, and Forbs			**Ferns**		
Abrus precatorius	0.01		*Nephrolepis biserrata*	1.25	
Atylosia scarabaeoides		0.01	*Nephrolepis hirsutula*	25.63	18.00
Chromolaena odorata	15.89	0.50	*Pteris quadriaurita*	0.13	0.01
Cyanthillium cinereum	0.89		**All Plants**	51.71	22.10
Desmodium incanum	1.03	0.01	Bare	0	0
Desmodium triflorum	2.65	1.26	Litter	48.25	78.00
Emilia sonchifolia		0.01	Rock	0.26	0
Jatropha gossypifolium	0.13				
Operculina ventricosa	0.01				
Phyllanthus amarus	0.01				
Ruellia prostrata	0.01				
Urena lobata/Triumfetta semitriloba	0.13				

Several other herbaceous species had lesser percentages of ground cover, including the probably native creeping grasses *Digitaria* spp. and 2 species of alien beggarweeds (*Desmodium incanum* and *D. triflorum*). A second native species of swordfern (*N. biserrata*) also had >1% ground cover. Other species, including *Casuarina equisetifolia* seedlings or basal shoots, had very low cover in ironwood forest plots.

Transect 5, which sampled ironwood forest on the west side of northern Pagan, had a very high percentage of litter cover, composed mostly of ironwood branchlets. Live plant cover made up only 22.1% of the plot totals and was dominated by the native *Nephrolepis hirsutula* fern. As was seen in plots of

transect 4, the native grasses *Digitaria* spp. and alien beggarweed *Desmodium triflorum* also had >1% cover each. Other species with <1% cover each in plots of transect 5 included native tree seedlings, *Psidium guajava* seedlings, 3 alien herbs, the native vine *Atylosia scarabaeoides*, a native sedge, and the fern *Pteris quadriaurita*.

Shrubland of Northern Pagan

A shrubland dominated by the native *Dodonaea viscosa* (hopseed bush or *lampauye*) was found north of transect 2 in the southeastern part of northern Pagan Island (Fig. 1) and was sampled with 3 randomly-selected plots of 10 by 20 m. The substrate in this expanse of shrubland was a relatively recent lava flow with a covering of cinder or tephra. Few trees were scattered in this shrubland; only a single large *Ficus prolixa* fig tree and very small, shrubby *Psychotria mariana* were counted in vegetation plots. Because of its large diameter and basal area, *Ficus prolixa* was the dominant tree of the shrubland (Table 16). Both tree species probably originated from the adjacent native forest via bird dispersal of their small fleshy fruits.

Table 16. Density, Mean Basal Area, and Dominance of Tree Species in Plots (600m^2 total) of *Dodonaea viscosa* Shrubland on Northern Pagan.

Shrubland PlotsTotal (3)	MeanBA (cm^2)	#trees	Dominance ($cm^2/600m^2$)	Dominance (m^2/ha)	Rank
Ficus prolixa	1384.74	1	1384.74	2.31	1
Psychotria mariana	5.13	4	20.50	0.03	2

More than a third (35.8%) of the pooled shrubland plots was bare cinder or soil, and another 9.3% was rocky lava substrate (Table 17). Live plant cover made up >40% of the plots and the native shrub *Dodonaea viscosa* was the dominant plant, with 18.2% ground cover. Small *Psychotria mariana* shrubs had

Table 17. Ground Cover (%) in Pooled Plots of Shrubland and Grassland on Northern Pagan.

Tree and Shrub Species	Shrubland	Grassland	Sedges and Grasses	Shrubland	Grassland
Dodonaea viscosa	18.17		*Bothriochloa bladhii*		9.20
Psychotria mariana	2.50		*Chloris barbata*		0.02
Low Shrubs, Vines, Forbs			*Chrysopogon aciculatus*	0.20	23.10
Alysicarpus vaginalis	0.17	0.62	*Cynodon dactylon*		0.10
Atylosia scarabaeoides	2.50		*Cyperus cyperinus*	0.02	
Cassytha filiformis	0.33		*Cyperus polystachyos*	0.05	
Chamaesyce thymifolia		0.01	*Dactylotenium aegyptium*		0.01
Chromolaena odorata		1.90	*Digitaria* spp.	5.67	12.20
Cyanthillium cinereum		0.01	*Fimbristylis* spp.	0.35	0.10
Desmodium triflorum	2.17	6.30	*Heteropogon contortus*	0.35	
Hedyotis corymbosa	0.03	0.03	*Miscanthus floridulus*	0.18	
Hyptis pectinata	0.02		*Sporobolus fertilis*	0.02	0.90
Jatropha gossypifolia		0.50	**Ferns**		
Phyllanthus amarus	0.02		*Cheilanthes tenuifolia*	0.02	
Portulaca pilosa		2.31	*Nephrolepis hirsutula*	7.17	
Sida acuta	0.03	6.90	**All Plants**	41.37	64.84
Spermacoce assurgens		0.10	Bare	35.83	18.60
Stachytarpheta jamaicensis	0.35	0.21	Litter and Manure	13.83	16.50
Tridax procumbens	1.02	0.31	Rock	9.33	0.20
Waltheria indica	0.05	0.01			

an additional 2.5% cover. The most prominent herbaceous plants of the shrubland were the swordfern *Nephrolepis hirsutula* (7.2%), the vine *Atylosia scarabaeoides* (2.5%), the probably native creeping crabgrass or *Digitaria* spp. (5.7%), and the low herbaceous alien beggarweed *Desmodium triflorum* (2.2%) and coatbuttons or *Tridax procumbens* (1.0%). Seven additional alien herbs and low shrubs, 7 native sedges and grasses, a vine, and a tiny fern each had very low cover (<1%) within shrubland plots.

Grassland of Northern Pagan

Grasslands composed of the native low-growing *Chrysopogon aciculatus* mixed with other grasses were widespread on the southern slope of the northern

section of the island and were sampled with 5 vegetation plots randomly placed along the jeep road from the old village site and camp on the western shore to the southern coastline at Degusa Beach. The swordgrass, *Miscanthus floridulus*, grasslands of the isthmus connecting the northern and southern halves of the island were not sampled because of difficult terrain.

Northern grasslands had high live plant cover (64.8%), and less than a quarter of sampled plots were bare exposed soil (18.6%) (Table 17). *Chrysopogon aciculatus* was the dominant grass with 23.6% cover, but the alien *Bothriochloa bladhii* and probably native *Digitaria* spp. (mixed crabgrass) were also common with 9.2% and 12.2% cover, respectively. The non-native herbaceous sub-shrubs *Desmodium triflorum* (6.3%) and *Sida acuta* (6.9%) also had relatively high cover, as did the succulent alien herb *Portulaca pilosa* (2.3%). The weedy shrub *Chromolaena odorata* was present with 1.9% cover, and 9 other alien herbaceous forbs or low shrubs had <1% cover each. The rest of the ground cover was composed of trace amounts of both native and alien grasses and sedges, as well as litter and animal droppings, particularly those of wild cattle.

Species Composition of the Vascular Plant Flora of Pagan

A total of 215 vascular plant species was observed on Pagan during field work in June and July 2010. Most of the observed plants were flowering plants including 146 taxa (species and varieties) of dicotyledons (broad-leaved plants) and 48 species of monocotyledons (Table 18). Additionally, 20 fern species and 1 cycad (a Gymnosperm) were seen on the island. Most of the ferns were indigenous (native) species; only 2 fern species seen on the island were alien in origin. The flowering plants were a combination of alien (including a few likely aboriginal Chamorro introductions) and native species. Among the dicotyledons,

Table 18. Summary of Vascular Plant Taxa Observed on Pagan Island in June-July 2010.

Plant Group	Status	# Taxa	Plant Group	Status	# Taxa
Ferns	Alien	2	Gymnosperms	Alien	0
	Chamorro	0		Chamorro	0
	Indigenous	18		Indigenous	1
	Total	20		Total	1
Flowering Plants - Dicots	Alien	75	Flowering Plants - Monocots	Alien	20
	Chamorro	1?		Chamorro	4?
	Indigenous	70		Indigenous	23
	Total	146		Unknown	1
All Plants	Alien	97		Total	48
	Chamorro	5?			
	Indigenous	112			
	Unknown	1			
	Total	215			

there were 70 indigenous species and 76 alien or introduced species. Among the monocots were 23 indigenous species, 4 likely Chamorro introductions, 20 alien plant species, and 1 grass of uncertain status. A complete checklist of plants seen in 2010 or previously reported from Pagan is presented in Appendix II.

Determination of the status of plants as alien or native (indigenous to Pagan and indigenous or endemic to the Marianas) and nomenclature of plants in the appendix checklist followed the checklists of Micronesian plants by Fosberg *et al*. (1979, 1982, 1986), except where recent publications were used for names of a few ferns (Palmer 2003, Holttum 1977), grasses (Clayton and Snow 2010), alien plants (Wagner *et al*. 1999), and native plants (Raulerson 2006).

Species not observed in 2010 – Based on a vascular plant checklist compiled from previously published sources (Fosberg 1958, Fosberg and Corwin 1958, Fosberg *et al*. 1975, Fosberg *et al*. 1979, Fosberg *et* al. 1982, Fosberg *et al*. 1986, Raulerson 2006) and specimens stored at the Bishop Museum and the Herbarium of the University of Guam, 267 vascular plant species were reported

from Pagan Island prior to 2010. Including the new plant records from the current survey, the total number of plants species known from Pagan is 299. Comparing this checklist of reported species with that of the species observed in 2010, there were 84 vascular plant species previously known from Pagan that we did not observe during our survey. Only 8 previously reported ferns were not seen in 2010; these included 2 ferns last reported from Pagan in the 1930s, 2 swordferns (*Nephrolepis*) that we did not distinguish from the common *N. hirsutula* but are very likely still present, and 2 native *Pteris* spp. listed by Raulerson (2006).

Two of the remaining ferns may have been lost from the island. *Acrostichum aureum* is a wetland fern previously reported and collected only near Sanhalom Lake, which we surveyed without observing the species. The fern ally *Selaginella ciliaris* was previously collected from the lake, as well as in the forest of the old caldera wall (University of Guam Herbarium); both areas were surveyed in 2010 without finding this small terrestrial plant. *Selaginella* was also known previously from the summit crater of Mt. Pagan prior to the last eruption (Raulerson and Rinehart 1992).

Among the flowering plants known from Pagan, there were 46 dicots and 30 monocots not seen in 2010. A few of these species (4) were only known from the fossil record (Fosberg and Corwin 1958), and another 15 have not been reported from the island since the 1930s (Fosberg 1958, Fosberg *et al*. 1975). Thirteen other species not observed in 2010 were cultivated plants >40 years ago and have likely disappeared from the island. Several native plants (4) were collected only on Mt. Pagan prior to its eruption in 1981 (Fosberg *et al.* 1975), and these may have been lost from the island. A few species (perhaps 6) not seen in 2010 are typical coastal plants (e.g., *Wollastonia biflora*, *Vigna marina*, the grass *Thurarea involuta*) and may remain on some of the rugged coastlines not traversed during this survey. The remaining 34 flowering plant species previously reported from the island may persist in unsurveyed portions of Pagan,

particularly in the rugged southern part of the island. It is likely that many of the 14 grasses and sedges previously observed on the island but not seen in 2010 are still present; if mixed with more common grasses in areas grazed by feral cattle they would be difficult to identify.

New island records of plants – Thirty-three vascular plant species observed on Pagan Island in 2010 had not been previously listed as present on the island (Fosberg 1958; Fosberg and Corwin 1958; Fosberg *et al*. 1975, 1979, 1982, 1986; Raulerson 2006) and were not documented among the herbarium specimens at the Bishop Museum or University of Guam. While there may be specimens of some of these species preserved at other herbaria not examined, it is likely that most of these observations were new records for the island. Most of the new records were of alien plants (21). Apart from 4 ornamental and fruit-bearing species that appeared to be intentionally planted within the old village site on the west coast of northern Pagan (*Asparagus* cf. *densiflorus*, *Canna* sp., *Eugenia uniflora*, and *Phyllanthus acidus*), most of these new aliens were probably accidental introductions and recent arrivals. Notable among these alien plant records were *Coccinia grandis* (ivy gourd), *Mikania micrantha* (mile-a-minute vine), and *Lantana camara* (lantana), which are considered serious weeds on Guam and Saipan (McConnell and Gutierrez 2006; L. Williams, pers. comm.).

Among the potential new records for Pagan Island were 12 native plants. The native cycad *Cycas circinalis* (*fandang*) was observed and collected in ravines of the southern part of the island, where it grew to great size. Three tree species previously unreported on Pagan were collected in native forests of the south; these were *Cordia subcordata* (*niyoron*), *Cynometra ramiflora* (*gulos*), and *Pisonia grandis* (*umumu*). Other native plants collected on southern Pagan that appear to be new records were the tiny composite *Lagenophora lanata*, seen only near the southern peaks of the island (E. Cook, pers. comm.), and the small shrub *Chamaesyce serrulata* found on a rocky slope dominated by native grasses. Two native ferns were observed in southern forests and not elsewhere;

these were *Cyclosorus interruptus* and *Christella parasitica*, both terrestrial ferns of moist areas formerly placed in the genus *Thelypteris* (Raulerson and Rinehart 1992). One grass, tentatively identified as the indigenous *Garnotia stricta*, was common in forests of the southern part of the island.

Only 2 possible new records were observed exclusively on the northern part of the island; these were the ephemeral native fern *Ophioglossum nudicaule* and the coastal vine *Boerhavia* sp. (most likely *B. repens*). The fern was observed following a rain event on the airstrip near the camp, and *Boerhavia* was seen only once in a deep crack at Inae Dikiki, a coastal site on the southeastern coast. The sprawling prickly shrub *Caesalpinia major* (*pakao* or wait-a-bit) was collected once in ravine forest of the far south and observed once near Talague Beach on the north coast of the island.

Vegetation of special areas –Sanhiyong Lake and the interior Sanhalom Lake of the northwestern side of Pagan were visited once, and a list was made of plants present on the perimeters of both lakes. The tidal lake of Sanhiyong was separated from the sea by a narrow berm of black sand that was almost devoid of plants. Only the native sedge *Fimbristylis cymosa* and the coastal vine *Ipomoea pes-caprae* were noted on this western side of the lake. The forest surrounding Sanhiyong on the north, east, and south was dominated by *Casuarina equisetifolia* with scattered native trees such as *Ficus tinctoria*, *Morinda citrifolia*, *Terminalia catappa, Hernandia sonora* (*nonak*), patchy *Hibiscus tiliaceus*, and the non-native *Leucaena leucocephala*. Groups of *Cocos nucifera* palms were also prominent on the edge of the lake. The only wetland vegetation seen on the verge of Sanhiyong was a patch of the native saltgrass *Paspalum vaginatum* on the north shore. Other grasses, such as *Digitaria* spp. and the aliens *Chloris barbata* and *Paspalum conjugatum*, were rare on the lake shore, as were the native sedges *Cyperus polystachyos* and *C. javanicus*. Several alien herbaceous plants were common but had little cover near the western lake: little ironweed or *Cyanthillium cinereum*; the spurge *Phyllanthus amarus;* and

beggarweed, *Desmodium triflorum*. Two native ferns, *Pteris quadriaurita* and *Sphenomeris chinensis*, were scattered along the edge of Sanhiyong, and a single young tree fern, *Cyathea aramaganensis,* was observed on the southern shore.

Sanhalom Lake, at higher elevation to the northeast of Sanhiyong Lake, was also surrounded primarily by forest of *Casuarina equisetifolia* or ironwood. Patches of native trees were mixed with ironwood and were common on the steep northern slope descending to the lake. Native tree species of the lakeside ironwood forest included *Ficus prolixa*, *F. tinctoria*, *Aglaia mariannensis*, *Pandanus tectorius*, *Morinda citrifolia*, *Melanolepis multiglandulosa*, and *Terminalia catappa*. A few coconut palms were also seen around the lake. The native swordgrass *Miscanthus floridulus* and *Heteropogon contortus* were seen on the steep rocky slopes north and northeast of the lake. The muddy verge of Sanhalom Lake showed signs of animal trampling and supported few plants other than native sedges *Fimbristylis* spp. and *Cyperus polystachyos*, a few patches of alien grasses (*Chloris barbata*), and the native ferns *Pteris quadriaurita* and *Sphenomeris chinensis*. All plant species observed around Sanhalom Lake were also seen elsewhere on the island; none was unique to this habitat.

Lava flows of the north and northeast slope of Mt. Pagan were traversed in transit to forest patches sampled along transect 8 on the northeast side of the island. The lava flows and cinder fields of Mt. Pagan were almost devoid of any vegetation. Only low depressions with depositions of fine ash supported low herbaceous vegetation. Species seen in these ash-filled lava swales were the sedges *Fimbristylis cymosa*, *F. dichotoma*, and *Cyperus polystachyos*; mixed grasses such as *Digitaria* spp. *Dactylotenium aegyptium*, and *Sporobolus fertilis*; and the creeping introduced herbs *Hedyotis corymbosa* and *Desmodium triflorum*.

Inae Dikiki (or Unae Rikiki), a bay at the southeasternmost tip of the northern half of the island, had steep cliffs at its southern end that supported the only *Pemphis acidula* (*nigas*) shrubs seen on Pagan Island. *Pemphis* is a characteristic plant of limestone coasts in the Mariana Islands (Raulerson and Rinehart 1991). These cliffs also had a patch of the coastal shrub *Capparis cordifolia*, which was otherwise seen only on a steep cliff of the far southwest coast. Just north of the boulders that defined the edge of Inae Dikiki was an open grassland, and this was one of the few areas where the native low-growing succulent herbs *Portulaca australis* and *P. oleracea* were seen on the island. Vegetation along the shoreline at Inae Dikiki was a mat of native *Zoysia matrella* grass mixed with creeping crabgrass *Digitaria* spp. and non-native *Cynodon dactylon* (Bermuda grass), the native sedges *Fimbristylis cymosa* and *Cyperus javanicus*, and the introduced herb *Alysicarpus vaginalis*. Ravines and rocky areas behind the shore supported the native shrubs *Dodonaea viscosa* and *Vitex negundo* var. *bicolor* (*lagundi*), as well as the native sedge *C. javanicus* and the fern *Pteris quadriaurita*. Within a steep-sided depression was the only island sighting of *Boerhavia* sp., a vine typical of coastal strand vegetation. Typically common native coastal grasses, such as *Thuarea involuta* and *Lepturus repens*, were missing.

DISCUSSION

The vegetation observed on Pagan Island in 2010 did not represent original forest cover, but has been modified and shaped by 3 primary forces: cultivation and alteration of land cover by human inhabitants; the grazing and browsing actions of feral domestic animals; and transformation of volcanically active parts of the island by eruptions that have produced vast quantities of lava and tephra. Remnant forests examined in this survey were of 3 types: those dominated by the introduced coconut, mixed native forests with or without alien

trees, and ironwood forests on young substrates. Grasslands of the island may be natural or anthropogenic in origin (Fosberg 1960).

Coconut Forests

Coconut forests were prominent on both the northern and southern sections of the island of Pagan. These forests are, for the most part, in areas formerly used as coconut plantations (Fosberg *et al*. 1975, Mueller-Dombois and Fosberg 1998), but some mixed coconut forests of southern part of the island may represent remnant agricultural forests that were developed during the occupation of the original Chamorro people. Coconut forests and mixed coconut/native forests were estimated to cover 19% of the island in 2000 (Cruz *et al*. 2000). A more recent vegetation map of Pagan was recently produced by Haldre Rogers (F. Amidon, pers. comm.). While coconut palms were the dominant tree of these forests surveyed in 2010, even the simplest of the northern coconut groves had at least 3 native tree species in the canopy, and the most diverse had 8 native tree species mixed with the coconut palms. The coconut forests of the southern part of the island had 6-8 native tree species in addition to the palms. These native trees have likely moved into the plantations following cessation of copra production, and these forests represent a trend of secondary succession.

Native tree species, however, did not appear to be recruiting significant numbers of seedlings and saplings in the coconut forests, based on the mean density of woody plants <2 m height sampled in vegetation plots. On northern Pagan, with the exception of the coconut forest in the northeast that was separated from other vegetated areas by several kilometers of lava flows and cinder fields (transect 8), few native tree seedlings and almost no saplings 1-2 m tall were counted in coconut forests. Even sprouting coconuts were low in number and very few coconut plants >1 m were observed, so the dominant coconut tree does not seem to be reproducing and recruiting young trees in

these forests. Almost all sprouting coconuts showed signs of feeding by either cattle or goats, and ripped-up coconut husks were likely the result of feral pig action (although coconut crabs may also be present) (Cruz *et al*. 2000). Ground cover was composed mostly of coconut leaf litter, and few herbaceous plants occurred in the coconut forests. Feral animals, including cattle, goats, and pigs, appeared to be suppressing woody plant regeneration, and their grazing and browsing has resulted in low cover of living plants and the prevalence of bare areas with exposed soil. In other tropical forests, feral animals are known to damage woody plants by browsing and trampling (Stone 1985). Feral pigs, in particular, have been reported to suppress regeneration of trees and shrubs and expose soil to increased erosion on Guam of the Southern Mariana Islands (Conry 1988).

In the transect 8 coconut forest of the northeast slope that showed some recruitment of native tree seedlings, both feral cattle and pigs were observed, but feral goats were not seen. In this remote forest, there were 9 species of native trees represented by seedlings and 4 species present as saplings. The rough volcanic terrain surrounding these forest patches may have resulted in lower numbers of feral animals here. These forest patches have been separated from contiguous forest vegetation by rough lava flows for more than 50 years, as evidenced by photographs presented by Fosberg (1960). *Aglaia mariannensis* is thought to be resistant to feral pig damage on Guam (Perry and Morton 1999), and this tree was among those with seedlings and saplings in plots of transect 8 forest. *Aglaia mariannensis* size class distribution in the northeast coconut forest also displayed larger means for trees in the 1-5 and >5-10 cm diameter classes than in the larger diameter classes, indicating that its population may be capable of increasing though the addition of young trees (Barbour *et al.* 1980).

Previous vegetation surveys of Pagan in coconut forests near Degusa Beach and at other sites on northern Pagan also found very low numbers of native trees in diameter classes <10 cm and a lack of native tree seedling

regeneration, which was attributed to the presence of feral animals (Cruz *et al*. 2000). Feral goats have been shown to impact forest understory and to denude ground cover on other northern Mariana Islands, such as Anatahan (Worthington *et al*. 2001) and Agiguan (Aguijan) (Rice 1991). Improved native tree regeneration was observed on the island of Sarigan following the removal of feral goats and pigs (Kessler 2002).

Mixed Native Forests

Native forests, other than those dominated by *Casuarina equisetifolia*, were uncommon on northern Pagan and were seen only at the base of the old caldera wall and growing on rocky substrates of the eastern slope of this half of the island The forest along the caldera wall sampled by the current transect 1 appeared to be a remnant of formerly more widespread forest, and collections of native trees have been made from this area multiple times in the last 60 years (Fosberg *et al*. 1975; D. Herbst, 1984 specimens in Bishop Museum *Herbarium Pacificum*; A. Rinehart, 1996 specimens in University of Guam Herbarium), indicating that the forest has retained a relatively high diversity of native tree and shrub species. This same remnant forest was sampled in a vegetation survey in 2000 and was found to have a mix of native and alien tree species and few trees in diameter classes <10 cm (Cruz *et al*. 2000).

Prior to the eruption of 1981 and the release and feralization of domestic animals, native broad-leaf forests were reported from near Sanhalom Lake and on the north and south slopes of Mt. Pagan (Fosberg 1960). Sanhalom Lake in 2010 was surrounded by ironwood forest with only scattered individuals of other species, and both the north and south slopes of Mt. Pagan were covered by recent lava flows nearly devoid of vegetation. The most species-rich native forest sampled on northern Pagan in 2010 was that of transect 2 along the line

of the old caldera wall east of the main road to the south. This forest had the greatest number of native tree species of any forest sampled in 2010 on Pagan, approaching the 15 different trees reported for low-stature native forests of the northern part of the island in 1950 (Fosberg 1960). The rocky substrate of this diverse native forest likely deterred the digging of feral pigs, and rough uneven terrain may have impeded access by feral cattle. Grazing by cattle is known to interfere with native tree reproduction in Hawai`i (Baldwin and Fagerlund 1943), and exclosure studies have demonstrated the negative impacts that cattle have on native woody vegetation (Loope and Scowcroft 1985). One of the notable impacts of feral pigs in wet forests of Hawai`i is reduction of native woody plants and ferns (Stone *et al*. 1992, Loh and Tunison 1999, Pratt *et al*. 1999).

Native forests of the southern part of Pagan had slightly different tree species composition than were seen in the mixed native and alien forests of the northern half of the island, and some of the introduced trees found in the north (e. g, *Jatropha curcas*, *Psidium guajava*) were lacking in the south. Several native tree species were found in forests of the south that were not encountered on northern Pagan, including *Geniostoma rupestre* var. *glaberrimum* (formerly *G. micranthum*, *majlocjayo*) and *Aidia cochinchinensis* (*sumac*), which are relatively common understory tree and shrub species elsewhere in the Mariana Islands (Raulerson and Rinehart 1991). The overall density of several tree species, particularly in smaller size classes, and the number of woody plant saplings and seedlings were larger in forests of the south as compared to those of the north. The rugged nature of the southern forests, the lack of grazing cattle (Cruz *et al*. 2000), and the fact that the south has not been cultivated since the time of Chamorro inhabitation likely contributed to this greater native woody plant diversity and abundance.

Ironwood Forests

Ironwood forests of northern Pagan were extensive on both eastern and western slopes of Mt. Pagan. The forests sampled on the west and southwest side of Mt. Pagan displayed size class distributions of *Casuarina equisetifolia* suggesting stable populations (Barbour *et al.* 1980). Comparison of the mean basal area of ironwood trees with those in the mixed native forests sampled on the southern half of the island indicated smaller and apparently younger trees in forests of the north. This apparent youth of the ironwood forests on the northern part of the island is likely explained by the relatively young age of the substrates surrounding Mt. Pagan, with several recent historical flows and others only a few hundred years in age (Trusdell *et al*. 2006). Fifty years ago, many of the areas of northern Pagan now covered by ironwood forest were dominated by swordgrass *Miscanthus floridulus* with only scattered trees (Fosberg 1960). Then in 1981, a major eruption occurred at Mt. Pagan, and massive lava flows covered the north and south slopes of the volcano. Subsequently, tephra and cinder 100-300 cm thick were deposited on the west, south, and east slopes of Mt. Pagan (Trusdell *et al*. 2006).

Ironwood appears to be an early successional species in the Marianas, where it grows rapidly on new substrates and invades disturbed soils in secondary succession of unburned areas (Fosberg 1960). The dense layer of fallen needle-like branches in ironwood forests inhibits the establishment of understory species, at least in dry areas (Fosberg and Sachet 1975), and *Casuarina equisetifolia* is known to produce allelopathic compounds that deter the growth of other nearby plants (Smith 1985). However, at least 10 species of native woody plants were observed as seedlings and saplings along transects in ironwood forest, so the building blocks for a more diverse native forest are present on the island.

Although ironwood has the hallmarks of an invasive species (Cruz *et al*. 2000) and was intentionally planted in windbreaks around fields on Pagan Island prior to the Second World War (Fosberg and Corwin 1958, Fosberg 1960), the species is generally accepted as native in the Mariana Islands (Stone 1970, Fosberg *et al*. 1979). Ironwood has a widespread, apparently natural distribution in Micronesia and was collected in the Mariana Islands early in the historical period (Fosberg and Sachet 1975). Athens and Ward (1995) found *Casuarina* pollen at a marsh site on Guam distributed down to layers several thousand years old that represented the time of human inhabitation; they interpreted the species as an early prehistoric Chamorro introduction to the Mariana Islands. However, in a later study of Holocene vegetation on Guam (Athens and Ward 2004), *Casuarina* pollen was found in layers >6,000 years old, predating human settlement. Since *Casuarina equisetifolia* appears to be indigenous to Guam, it is likely native throughout the Marianas.

Shrublands and Grasslands

Shrublands of northern Pagan occurred on relatively young substrates and were composed mostly of native species. The shrublands observed in the 2010 survey occurred in areas where the tephra deposits from the 1981 eruption of Mt. Pagan were less than 50 cm in depth on historical (but not the most recent) lava flows (Trusdell *et al.* 2006). The presence of native tree species within the shrubland and the proximity of native forest indicate that shrublands on Pagan may be successional vegetation types that lead to forest vegetation. However, the presence of feral animals may alter the natural succession by reducing regeneration of some woody species. In some limestone forests of Saipan, native trees with small fleshy fruits (such as *Psychotria mariana*, which was present in sampled shrublands) have been found to recolonize disturbed forests even in the presence of feral animals (Craig 1993).

Grasslands of northern Pagan sampled in the current study, although typically composed of native grasses such as golden beardgrass *Chrysopogon aciculatus*, may not be natural but rather the result of past agriculture, fire, and continued impact of feral animals. *Chrysopogon aciculatus* is unpalatable to cattle and considered worthless as forage, and its aggressiveness, stoloniferous habit, ability to form dense mats close to the ground, and barbed seeds easily spread by animals give the grass an advantage in heavily grazed areas (Whitney *et al*. 1939, Chin 1985). Much of the south-facing part of northern Pagan, which in 2010 was covered by grassland and patchy forest, was formerly cultivated land prior to the Second World War, as seen in a U.S. Navy photo map of Pagan from the 1950s in the collection of the Bishop Museum of Honolulu. The lack of significant cover of tall *Miscanthus floridulus* in grasslands of the northern part of the island in 2010 was likely due to the grazing action of cattle, as swordgrass appeared to be the dominant grass in the adjacent isthmus connecting the northern and southern halves of the island, an area that is too steep for cattle to access (Cruz *et al*. 2000, Berger *et al*. 2005). Also swordgrass grassland was formerly a widespread vegetation type on northern Pagan prior to the eruption of 1981 (Fosberg 1960), before domestic cattle were apparently released to become feral. Previously, swordgrass grasslands were maintained by periodic burning (Mueller-Dombois and Fosberg 1998).

Alien Plant Species

Alien plants made up a significant percentage of the flora of Pagan, and it appeared that the alien component has continued to increase over the last 60 years. When Fosberg compiled a list of plant species reported from the island based on collections from 1930-1950, he listed 59 alien plant species and 8 Chamorro introductions (Fosberg 1958); a few grasses included among the aliens were later considered indigenous (Fosberg *et al.* 1982). At this time,

introductions were greatly outnumbered by indigenous plant species on the island. By 1975, the number of introduced species on Pagan (including aboriginal introductions) had increased to 79, with at least 12 alien plant species added to the known flora of Pagan based on the collections of Moore, Villagomez, and Falanruw in the 1970s (Fosberg *et al.* 1975).

Subsequent visits by botanists to Pagan resulted in continued incremental additions to the known flora of the island. At least 7 previously unreported alien plants were collected on Pagan by Lynn Raulerson in 1981 (University of Guam Herbarium), including *Tridax procumbens* or coat buttons, a noxious weed now widespread on the northern half of the island. When botanist Derral Herbst visited the island for 2 days in 1984, he added at least 8 non-native plant species to the flora of Pagan (Bishop Museum *Herbarium Pacificum*), including the widespread and highly invasive *Chromolaena odorata* (McConnell and Guttierrez 2006), as well as 3 fruit or ornamental trees that were probably intentionally introduced. In 1996, Agnes Rinehart documented at least 6 alien plant species previously unknown on Pagan Island (University of Guam Herbarium). One of these 1996 additions, the succulent purslane *Portulaca pilosa,* was abundant in 2010 within grasslands of the northern half of the island, while the 3 related native purslane species known from Pagan appeared to be rare. Another alien species first observed on island by Rinehart was the ornamental chain-of-love vine *Antigonon leptopus*. This species has been recognized as a fast-growing invasive alien in the Southern Marianas (McConnell and Gutierrez 2006, Berger *et al.* 2005), but in the current survey it seemed to be restricted to the area around camp and the old village on the west coast of northern Pagan. An additional non-native species was first observed on Pagan by the 2000 vegetation survey botanists (Cruz *et al.* 2000); this was Formosa koa, *Acacia confusa*, a tree that appeared to be intentionally planted at sites east of the abandoned village.

The current vegetation survey resulted in a list of 102 alien and introduced plant species on Pagan. This included collections or observations of

21 non-native plant species previously unrecorded for Pagan and not represented in herbaria of the Bishop Museum or the University of Guam. One species in this group of potential new records, *Abutilon indicum*, is questionably native to the Mariana Islands (Fosberg *et al.* 1979), although listed as non-native on Guam (Stone 1970). All of the alien plant records were seen on northern Pagan and none was noted on the southern half of the island, although the 2010 vegetation survey was not extensive in the rugged south. Most of the new alien plant records (at least 14) were seen only once or twice in limited areas and are probably at an incipient stage of invasion. The center of alien plant invasion appeared to be the area around the camp and within the old village site on the western coast of northern Pagan. Several alien plants were observed in 2010 only in disturbed areas along roads north and east of the camp and old village.

Notable among the new alien plant records was *Coccinia grandis*, ivy or scarlet gourd. This vine was seen only near the old village site and at a single point along the road north of the village. While more plants may be present than are currently known, it is probably feasible to eradicate the species from Pagan at present. *Coccinia grandis* has become a serious pest on Saipan and now covers more than 15,000 acres on that island (Berger *et al*. 2005). The vine is also known as an aggressive recent invader of dry lowland habitats in Hawai`i (Linney 1986). The mile-a-minute vine, *Mikania micrantha*, and the passionflower *Passiflora suberosa* were also sighted in the ruins of the old village at a single disturbed site. Both of these are aggressive vines that are considered invasive weeds on Guam (McConnell and Guiterrez 2006). Balloon vine *Cardiospermum halicacabum* and morning glory *Ipomoea triloba* (little bell) were also concentrated near the old village, but both these vine species were found at multiple sites and have clearly spread beyond the points of original introduction.

Three shrubs that may eventually become more widespread were noted at only few sites in 2010. *Lantana camara* was observed only once east of the old village (on transect 4) growing with *Coccinia grandis*. This ornamental species is

considered a serious pest in Hawai`i and has been the subject of much biocontrol work (Davis *et al.* 1992); its berries are spread by fruit-eating birds. Castor bean, *Ricinus communis*, was seen in a ravine in the old village and at a single site in the northern isthmus, while butterfly bush or *Buddleia asiatica* was seen at only 1 roadside point in the northwest as well as in the northern part of the isthmus. *Buddleia*, with its wind-borne seeds, is likely to spread farther on the island.

The steady addition of non-native plants to Pagan with 10-20 documented additions every decade and the appearance of invaders in areas of human use suggest that visitors are responsible for the probably inadvertent introduction of alien plant species to the island. A few ornamental species and fruit trees may have been intentionally introduced to the island. The findings of the current vegetation survey regarding new alien plant invaders of Pagan support the recommendation of the recent comprehensive plan for wildlife conservation in CNMI, which gave a high priority to the prevention of invasive species introductions to the Northern Mariana Islands (Berger *et al*. 2005).

Rare Native Plants

The addition of 12 native plant species to the known flora of Pagan documented in the current survey is encouraging and increases understanding of the native plant diversity of the island. Clearly, the southern part of the island has not been exhaustively searched, and it is likely that additional native plant species remain to be discovered in the forests and ravines of this rugged and much dissected region of Pagan.

Four apparent new records for Pagan Island were trees and a cycad restricted to one or few sites on the southern part of the island. *Pisonia grandis* was seen in native forest on the upper shelf of southern Pagan, as well as in

ravines close to the western coast and on the east coast (E. Cook, pers. comm.). This tree species is common in Micronesia, especially on atolls (Raulerson and Rinehart 1991), and has been collected on both Maug and Sarigan of the Northern Marianas (Fosberg *et al*. 1975). *Cordia subcordata* and *Cynometra ramiflora* were observed in ravine forest of the western coast, and *Cordia* was also sighted in sampled forests of the upper shelf of southern Pagan. *Cordia subcordata* is found throughout the Pacific (Mueller-Dombois and Fosberg 1998), but has been previously collected in the Mariana Islands north of Saipan only on Maug (Fosberg *et al*. 1975, 1979). *Cynometra* is also widespread in the Pacific and a common understory species of the Southern Marianas (Raulerson and Rinehart 1991), but has been collected in the Northern Marianas only on Sarigan and Farallon de Medinilla (Fosberg *et al*. 1975, 1979; Raulerson 2006). The cycad *Cycas circinalis* was found in large numbers within a ravine on the southwest. This common species of limestone areas in the Southern Marianas (Raulerson and Rinehart 1991) has not previously been collected north of Saipan (Fosberg *et al*. 1982, Raulerson 2006).

Other new records for Pagan of native plants that were only seen or collected on the southern half of the island included 2 terrestrial ferns (*Christella parasitica* and *Cyclosorus interruptus*), a small shrub (*Chamaesyce serrulata*) previously known only from the Southern Marianas (Fosberg *et al*. 1979), a grass (*Garnotia stricta*) known from Guam (Stone 1970), and a tiny herb of the sunflower family (*Lagenophora lanata*) native to southern Asia, Taiwan, Australia, and New Guinea (eFloras 2010) and previously noted in the Northern Marianas only on Alamagan (Raulerson 2006). The prickly shrub *Caesalpinia major* was found on both northern and southern sections of the island as single individuals; this indigenous species has apparently not been collected north of Tinian (Raulerson 2006, Fosberg *et al*. 1979).

Apart from the native plants that appeared to be new records, several other tree and fern species previously known from the island were only found on

southern Pagan during the survey of 2010. *Elaeocarpus joga* is among the tallest native trees of the Marianas (Raulerson and Rinehart 1991) and is thought to be one of the original dominant species of limestone forests in the south and remnant native forests of the Northern Marianas (Fosberg 1960, Mueller-Dombois and Fosberg 1998). This impressively large tree species was found only as scattered individuals in southern forests sampled along transects, but it was also observed in craters near the peaks of the south (E. Cook, pers. comm.). Other trees and shrubs seen in low numbers and seemingly restricted to the southern part of the island were *Aidia cochinchinensis*, *Geniostoma rupestre var. glaberrimum*, and *Eurya japonica* var. *nitida.* *Eurya japonica* is a small shrub, which was apparently last reported from Pagan in the 1930s (Fosberg 1958). *Geniostoma rupestre* includes plants from the Marianas formerly placed in *G. micranthum* (Conn 1980).

The epiphytic worm orchid, *Taeniophyllum marianense*, otherwise relatively common in the Marianas (Raulerson and Rinehart 1992), was of infrequent occurrence in the native forests of the southwest, as was *Piper betle*, a pepper vine that seemed to be planted near a patch of betel nut palms *Areca catechu*. The climbing pandan *Freycinetia reinecki* and the bird's nest fern *Asplenium nidus* (*galak*) were observed only in wet ravines and steep gulches of the south; both species are common in Southern Mariana forests (Stone 1970, Raulerson and Rinehart 1992). Several other ferns and fern allies were sighted only at higher elevations of the southern part of Pagan, including the matted fern *Dicranopteris linearis*, the terrestrial *Sphaerostephanos* (*Thelypteris*) *unitus*, and the fern allies *Lycopodiella cernua* (club moss) and *Psilotum nudum* (whisk fern).

The tree fern *Cyathea aramaganensis* (*tsatsa*) was observed on both the southern and northern parts of Pagan, although it was rare in the north. This conspicuous fern was seen in large numbers on ridges and upper slopes of southern Pagan, and it was visible from offshore. The tree fern has been previously noted from the island (Raulerson 2006), although we found no

herbarium specimens from Pagan (Fosberg 1958, Fosberg *et al.* 1982). On northern Pagan, only 3 widely separated tree fern individuals were seen on the bank of Sanhiyon Lake and in ravines of the north and west slopes. This fern produces a large number of spores and is probably easily spread, but may have a difficult time persisting on northern Pagan in the presence of grazing cattle. The tree fern has also been collected on Alamagan, Sarigan, and Anatahan of the Northern Marianas (Fosberg *et al*. 1975, Raulerson and Rinehart 1992).

Guamia mariannae was also found on both halves of the island, but occurred in greater numbers in the understory forest of the upper plateau in the south. On northern Pagan, only a few trees were seen in the remnant forest of the rocky ridge on the southeast side of the island. Clearly this Micronesian endemic has not been lost from the island as reported by Mueller-Dombois and Fosberg (1998), but its rarity indicates that the tree may not be as resistant to animal damage as speculated by Perry and Morton (1999).

Strand species were very rare on both northern and southern parts of Pagan Island; only the beach morning-glory *Ipomoea pes-caprae* and the sedge *Fimbristylis cymosa* were common in strand habitats on the island. The limestone-loving *Pemphis acidula* was found at only one site on a cliff at Inae Dikiki. Likewise, the coastal shrub *Capparis cordifolia* was seen persisting only on 2 cliff faces. Even the normally common strand plant *Sesuvium portulacastrum* and the widespread Indo-Pacific shrub *Scaevola taccada*, usually a dominant beach shrub in the Marianas (Raulerson and Rinehart 1991), were each observed on steep cliffs at single coastal sites. Other typical coastal plants seen only once or twice included the shrub *Myoporum boninense*, the herb *Lysimachia mauritiana*, and the succulent herbs *Portulaca lutea* and *P. australis*. Native grasses typical of shorelines in the southern Mariana Islands, such as *Lepturus repens* and *Thuarea involuta* (Stone 1970), were not observed on Pagan in 2010. The lack of coastal strand habitat is probably caused by either feral animal damage or human disturbance.

CONCLUSIONS

The forests of Pagan Island in 2010 have been shaped by past cultivation, the impacts of feral animals, and human disturbance. A number of non-native plants have been intentionally introduced and become a part of the island's flora, and the influx of unintentional introductions of alien plants has continued for at least 60 years. The future of the forests of Pagan is difficult to predict. The activities of feral animals have resulted in disruption of the ground cover and native understory in many areas, and most native tree and shrub species do not seem to be effectively recruiting new individuals into their populations. However, native plants persist on Pagan, and remnant forests remain even on the highly disturbed northern part of Pagan, providing a seed source of trees to promote secondary succession in depauperate ironwood forests, successional shrublands, and disturbed areas now covered by grassland. Forests of the southern half of the island appear to be more species-rich and resistant to animal damage and alteration. Since no exclosure studies or animal removal experiments have been carried out on Pagan, the fate of native forests is uncertain should ungulates be removed in selected areas, as suggested by Berger *et al*. (2005). However, the change in vegetation observed on islands where animals have been removed is evidence of the likely scenario of vegetation recovery; some alien vines (e. g., *Operculina ventricosa*) would probably increase immediately upon release from herbivory, and native trees and shrubs would likely be more successful at reproduction and seedling recruitment (Kessler 2002). Even today, the island of Pagan, the largest of the Northern Marianas, remains a reservoir of native Micronesian plants and an important example of succession on a very active volcano, and it has great potential as a future laboratory for understanding changes in native and alien plant composition and forest structure.

ACKNOWLEDGMENTS

The vegetation assessment was part of the Marianas Expedition Wildlife Suvey of 2010, a U.S. Fish and Wildlife project funded by the Department of Defense, U.S. Marines, through the Naval Facilities Engineering Command Pacific, Pearl Harbor, Hawai`i. Funding was also provided by the U.S. Geological Survey Terrestrial Ecosystems Program and the Pacific Island Ecosystems Research Center. Thanks are due to the biologists at the U.S. Fish and Wildlife Service, Ecological Services, Honolulu for all their planning and logistics efforts in support of this and other surveys on Pagan; I would particularly like to thank Curt Kessler, Fred Amidon, Earl Campbell, and Craig Clark.

Thane Pratt, Wildlife Biologist Emeritus of the U.S. Geological Survey, accompanied me and volunteered his assistance in all aspects of the Pagan vegetation survey. Four botanists of U.S. Fish and Wildlife Service assisted us with field work on Pagan, without which extensive field surveys would not have been possible: Dan Clark, Chelsie Javar, James Kwon, and Cheryl Phillipson. I thank them for their botanical expertise and cheerful field assistance. Biologists who participated in the forest bird surveys shared with us their sightings of plants on Pagan; I thank Jan Lepson, volunteer, Anne Marshall and Fred Amidon of the U.S. Fish and Wildlife Service, and Rachel Rounds of the Division of Fish and Wildlife, CNMI. Staff at the Pagan field camp established by the U.S. Fish and Wildlife Service provided critical logistical support, without which much of Pagan Island would have been inaccessible; I would like to particularly thank Jesse Omar and Tom McCall, the Pagan Island camp managers and boat coordinators, for their assistance and attention to safety. I appreciate the efforts of the captain and crew of the vessel "Micronesia" in transporting people and gear safely between Saipan and Pagan.

Special thanks are due to Laura Williams of the Division of Fish and Wildlife, Commonwealth of the Northern Mariana Islands, for her advice, plant

sightings, and facilitation of permits to collect plant specimens on the island. Eric Cook, a volunteer with the U.S. Geological Survey herpetology survey team, assisted us immensely with his plant sightings and specimen collections from otherwise unvisited areas of the island. He also provided us with information from specimens at the University of Guam Herbarium. I also appreciate the help of Dr. Lynn Raulerson, preeminent ecologist and botanist of the University of Guam, for facilitating access to the herbarium. Staff at the Bishop Museum in Honolulu allowed me access to the Pacific collection of the *Herbarium Pacificum* and provided me with information on previous collections and plant checklists from Pagan; I am particularly grateful to Napua Harbottle, Clyde Imada, and Neal Evenhuis. A draft of this report was reviewed by Marie Bruegmann and Earl Campbell of the U.S. Fish and Wildlife Service, Honolulu, Arthur Medeiros of the U.S. Geological Survey, Pacifc Island Ecosystems Research Center, and Neal Evenhuis of the Bishop Museum, Honolulu. I greatly appreciate their review comments and helpful suggestions.

LITERATURE CITED

Athens, J. S., and J. V. Ward. 1995. Paleoenvironment of the Orote Peninsula. Micronesica 28:51-76.

Athens, J. S., and J. V. Ward. 2004. Holocene vegetation, savanna origins and human settlement of Guam. Pp. 15-30 *in* Attenbrow, V., and R. Fullagar (editors). A Pacific odyssey: archaeology and anthropology in the Western Pacific. Papers in honour of Jim Sprecht. Records of the Australian Museum, Supplement 29. Australian Museum, Sydney.

Baldwin, P. H., and G. O. Fagerlund. 1943. The effect of cattle grazing on koa reproduction in Hawaii National Park. Ecology 24:118-124.

Barbour, M. G., J. H. Burk, and W. D. Pitts. 1980. Terrestrial plant ecology. The Benjamin/Cummings Publishing Company, Menlo Park, California. 604 pp.

Bellwood, P. S. 1989. The colonization of the Pacific: some current hypotheses. Pp. 1-59 *in* Hill, A. V. S., and S. W. Serjeantson (editors). The colonization of the Pacific; a genetic trail. Clarendon Press, Oxford, United Kingdom.

Berger, G. M., J. Gourley, and G. Schroer. 2005. Comprehensive wildlife conservation strategy for the Commonwealth of the Northern Mariana Islands. Commonwealth of the Northern Mariana Islands, Department of Land and Natural Resources, Division of Fish and Wildlife, Saipan. 358 pp.

Chin, C.-T. 1985. Common weeds of Guam. Guam Agricultural Experiment Station, University of Guam. 64 pp.

Clayton, W. D., and N. Snow. 2010. A key to Pacific grasses. Kew Publishing, Royal Botanic Gardens, Kew, United Kingdom. 107 pp.

Conn, B. J. 1980. Revision of *Geniostoma* subgenus *Geniostoma*. Blumea 26:245-364.

Conry, P. J. 1988. Management of feral and exotic game species on Guam. Transactions of the Western Section of the Wildlife Society 24:26-30.

Corwin, G., L. D. Bonham, M. J. Terman, and G. W. Viele. 1957. Military geology of Pagan, Marianas Islands. U.S. Army Corps of Engineers, Intelligence Dossier. 259 pp. Original not seen, cited by F. A. Trusdell, R. B. Moore, and M. K. Sato. 2006. Preliminary geologic map of Mount Pagan Volcano, Pagan Island, Commonwealth of the Northern Mariana Islands. U.S. Geological Survey Open File Report 2006-1386.

Craig, R. J. 1993. Regeneration of native Mariana Island forest in disturbed habitats. Micronesica 26:99-108.

Cruz, J., L. Arriola, N. Johnson, and G. Beauprez. 2000. Wildlife and vegetation surveys, Pagan 2000. 2000 Technical Report #7. Commonwealth of the Northern Mariana Islands, Division of Fish and Wildlife (Wildlife Section) with assistance from the Northern Island Mayor's Office. Saipan, CNMI. 68 pp.

Davis, C. J., E. Yoshioka, and D. Kageler. 1992. Biological control of lantana, prickly pear, and Hāmākua pāmakani in Hawai`i: a review and update. Pp. 411-431 *in* Stone, C. P., C. W. Smith, and J. T. Tunison (editors). Alien plant invasions in native ecosystems of Hawaii: management and research. University of Hawaii Cooperative National Park Resources Studies Unit, Honolulu.

efloras.org. 2010. *Lagenophora lanata* in Digital flora of Taiwan. [http://efloras.org/florataxon.aspx?flora_id=100&taxon_id=242413507.] Accessed 7/14/2010.

Evans, W. C., T. S. Presser, L. D. White, and I. Barnes. 1987. The volatiles of Mt. Pagan, Northern Marianas Islands. Pacific Science 41:90-103.

Fosberg, F. R. 1958. Vascular flora of Pagan Island, Northern Marianas. Pacific Science 12:17-20.

Fosberg, F. R. 1960. The vegetation of Micronesia; general descriptions, the vegetation of the Marianas Islands, and a detailed consideration of the vegetation of Guam. Bulletin of the American Museum of Natural History 119:1-76.

Fosberg, F. R., and G. Corwin. 1958. A fossil flora from Pagan, Mariana Islands. Pacific Science 12:3-16.

Fosberg, F. R., M. V. C. Falanruw, and M.-H. Sachet. 1975. Vascular flora of the Northern Marianas Island. Smithsonian Contributions to Botany Number 22. Smithsonian Institution Press, Washington, DC. 45 pp.

Fosberg, F. R., and M.-H. Sachet. 1975. Flora of Micronesia 2: Casuarinaceae, Piperaceae, and Myricaceae. Smithsonian Contributions to Botany No. 24. Smithsonian Institution Press, Washington, DC. 28 pp.

Fosberg, F. R., M.-H. Sachet, and R. Oliver. 1979. A geographical checklist of the Micronesian Dicotyledonae. Micronesica 15:41-295.

Fosberg, F. R., M.-H. Sachet, and R. Oliver. 1982. Geographical checklist of the Micronesian Pteridophyta and Gymnospermae. Micronesica 18:23-82.

Fosberg, F. R., M.-H. Sachet, and R. Oliver. 1986. A geographical checklist of the Micronesian Monocotyledonae. Micronesica 20:19-129.

Holttum, R. E. 1977. The family Thelypteridaceae in the Pacific and Australasia. Allertonia 1:169-234.

Kessler, C. C. 2002. Eradication of feral goats and pigs and consequences for other biota on Sarigan Island, Commonwealth of the Northern Mariana Islands. Pages 132-140 *in* Veitch, C. R., and M. N. Clout (editors). Turning the tide: the eradication of invasive species. IUCN SSC Invasive Specialist Group. IUCN, Gland, Switzerland and Cambridge, United Kingdom.

Linney, G. 1986. *Coccinia grandis* (L.) Voigt: a new cucurbitaceous weed in Hawai`i. Newsletter of the Hawaiian Botanical Society 25:3-5.

Loh, R. K., and J. T. Tunison. 1999. Vegetation recovery following pig removal in `Ola`a-Koa rainforest unit, Hawaii Volcanoes National Park. Technical Report 123. Pacific Cooperative Studies Unit, University of Hawai`i at Mānoa, Department of Botany, Honolulu. 31 pp.

Loope, L. L., and P. G. Scowcroft. 1985. Vegetation response within exclosures in Hawai`i: a review. Pp. 377-402 *in* Stone, C. P., and J. M. Scott (editors). Hawai`i's terrestrial ecosystems: preservation and management. Cooperative National Park Resources Studies Unit, University of Hawaii, Honolulu.

Marshall, A. and F. Amidon. 2010. Status of the wetland avifauna on Pagan, Mariana Islands. Report to U.S. Fish & Wildlife Service, Honolulu.

McConnell, J., and L. Gutierrez. 2006. Color atlas of common weeds of Guam. Agricultural Experiment Station, University of Guam. 130 pp.

Mueller-Dombois, D., and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley & Sons, New York. 547 pp.

Mueller-Dombois, D., and F. R. Fosberg. 1998. Vegetation of the tropical Pacific islands. Ecological Studies, Volume 132. Springer Verlag, New York. 733 pp.

National Aeronautic and Space Administration (NASA). 2009. NASA Earth Observatory. Pagan Island, Northern Marianas Islands: image of the day. [http://earthobservatory.nasa.gov/IOTD/view, accessed 12/3/2009.]

Palmer, D. D. 2003. Hawai`i's ferns and fern allies. University of Hawai`i Press, Honolulu. 324 pp.

Perry, G., and J. M. Morton. 1999. Regeneration rates of the woody vegetation of Guam's Northwest Field following major disturbance: land use patterns, feral ungulates, and cascading effects of brown tree snake. Micronesica 31:125-142.

Pratt, L. W., L. L. Abbott, and D. K. Palumbo. 1999. Vegetation above a feral pig barrier fence in rain forests of Kilauea's East Rift, Hawaii Volcanoes National Park. Technical Report 124. Pacific Cooperative Studies Unit, University of Hawai`i at Manoa, Department of Botany, Honolulu. 88 pp.

Raulerson, L. 2006. Vascular plant distribution in the Mariana Islands. University of Guam Herbarium Contributions 3:1-69.

Raulerson, L., and A. Rinehart. 1991. Trees and shrubs of the Northern Mariana Islands. Coastal Resources Management, Office of the Governor, Commonwealth of the Northern Mariana Islands, Saipan, Northern Mariana Islands. 120 pp.

Raulerson, L., and A. Rinehart. 1992. Ferns and orchids of the Mariana Islands. Lynn Raulerson and Agnes Rinehart Publishers, American Printing Corp., Guam. 138 pp.

Rice, C. G. 1991. Goat removal from Aguijan Island: lessons for future efforts. Transactions of the Western Section of the Wildlife Society 27:42-46.

Smith, C. W. 1985. Impact of alien plants on Hawai`i's native biota. Pp. 180-250 *in* Stone, C. P., and J. M. Scott (editors). Hawai`i's terrestrial ecosystems: preservation and management. Cooperative National Park Resources Studies Unit, University of Hawaii, Honolulu.

Stone, B. C. 1970. The flora of Guam. Micronesica 6:1-629.

Stone, C. P. 1985. Alien animals in Hawai`i's native ecosystems: toward controlling the adverse effects of introduced vertebrates. Pp. 251-297 *in* Stone, C. P., and J. M. Scott (editors). Hawai`i's terrestrial ecosystems: preservation and management. Cooperative National Park Resources Studies Unit, University of Hawaii, Honolulu.

Stone, C. P., L. W. Cuddihy, and J. T. Tunison. 1992. Responses of Hawaiian ecosystems to removal of feral pigs and goats. Pp. 666-704 *in* Stone, C. P., C. W. Smith, and J. T. Tunison (editors). Alien plant invasions in native ecosystems of Hawaii: management and research. University of Hawaii Cooperative National Park Resources Studies Unit, Honolulu.

Trusdell, F. A., R. B. Moore, and M. K. Sato. 2006. Preliminary geologic map of Mount Pagan Volcano, Pagan Island, Commonwealth of the Northern Mariana Islands. U.S. Geological Survey Open File Report 2006-1386. [http://pubs.usgs.gov/of/2006/1386/of2006-1386text.pdf]

Wagner, W. L., D. R. Herbst, and S. H. Sohmer. 1999. Manual of the flowering plants of Hawai`i. Revised edition. 2 volumes. Bishop Museum Special Publication 97. University of Hawai`i Press and Bishop Museum Press, Honolulu. 1919 pp.

Whitney, L. D., E. Y. Hosaka, and J. C. Ripperton. 1939. Grasses of the Hawaiian ranges. Hawaii Agricultural Experiment Station. Bulletin No. 82. University of Hawaii, Honolulu.

Worthington, D. J., A. P. Marshall, G. J. Wiles, and C. C. Kessler. 2001. Abundance and management of Mariana Fruit Bats and feral ungulates on Anatahan, Mariana Islands. Pacific Conservation Biology 7:134-142.

Appendix I

UTM Coordinates for Vegetation Plots at Stations along Forest Bird Survey Transects and Supplemental Grass and Shrubland Plots. All Coordinates are in WGS84, UTM Zone 55 North.

Transect	Station	X	Y	Transect	Station	X	Y
1	2	369188	2003736	9	2	364088	1998036
1	5	369638	2003586	9	4	364088	1998336
1	8	370388	2003436	9	6	364214	1998649
1	11	370838	2003286	9	8	364389	1998799
2	2	371738	2003394	9 Sup.*	1	364045	1997934
2	5	372180	2003639	9 Sup.*	2	364007	1997380
2	8	372552	2003586	9 Sup.*	3	364005	1997994
2	11	372282	2003142	10	2	363942	1997620
3	1	368831	2003282	10	4	363873	1997336
3	4	368647	2003290	10	6	363823	1997008
3	7	368699	2002814	10	8	363754	1996719
3	10	369005	2002744	11	B	365307	1997189
4	2	369188	2004636	11	1	364977	1997249
4	5	369488	2004786	11	3	364689	1997333
4	8	369638	2005086	11	5	364388	1997436
4	11	369589	2005292	11 N	6	364567	1997723
5	1	368588	2006736	11 N	8	364251	1997733
5	4	369038	2006736	11 N	10	364431	1998003
5	7	369488	2006736	11 N	12	364358	1998292
5	10	369913	2006644	14	3	370838	2002686
6	2	368895	2008230	14	6	371138	2002686
6	5	369333	2008229	14	9	371588	2002686
6	8	369764	2008246	14	12	371888	2002686
6	11	370232	2008234	Shrub*	1	371742	2003505
7	1	370838	2008836	Shrub*	2	371744	2003592
7	4	371288	2008836	Shrub*	3	371874	2003728
7	7	371738	2008836	Grass*	1	369191	2003935
7	9	372038	2008836	Grass*	2	371966	2003030
8	1	372788	2008036	Grass*	3	371796	2003359
8	4*	372981	2007925	Grass*	4	371483	2003257
8	7	373388	2007336	Grass*	5	371290	2003299
8	10	373538	2007036				
* Vegetation plots supplemental to or differing from forest bird survey transect stations							

APPENDIX II

Vascular Plant Species of Pagan Island,

Commonwealth of the Northern Mariana Islands

Group/Family	Scientific Name	Status	Observed 2010	Abundance	Localities observed 2010/Notes
FERNS					
Aspleniaceae	*Asplenium laserpitiifolium* Lam.	I		n/a	Not seen, collected in 1930s
Aspleniaceae	*Asplenium nidus* L.	I	X	U	Southern Pagan ravines on steep cliffs
Aspleniaceae	*Asplenium unilaterale* Lam.	I		n/a	Not seen, collected in 1930s
Cyatheaceae	*Cyathea aramaganensis* Kaneh.	I	X	R	Southern Island near peaks and craters, one plant at Talague, one at Sanhiyong Lake, and one in a ravine in the northeast
Davalliaceae	*Davallia solida* (Forst. f.) Sw.	I	X	C	Coconut and native forest epiphyte
Gleicheniaceae	*Dicranopteris linearis* (Burm. F.) Underw.* (Syn: *Gleichenia linearis*)	I	X	U	Southern Island near peaks
Lindsaeaceae	*Lindsaea ensifolia* Sw.	I	X	U	Mostly in the south and Isthmus
Lindsaeaceae	*Sphenomeris chinensis* (L.) Maxon subsp. *biflora* (Kaulf.) Jotani & Ohba	I	X	U	Southern Pagan and Sanhalom Lake
Lycopodiaceae	*Lycopodiella cernua* (L.) Pic. Serm.* (Syn: *Lycopodium cernuum*)	I	X	U	Southern Pagan only
Nephrolepidaceae	*Nephrolepis biserrata* (Sw.) Schott	I	X	C	Common in south, rare in northern part of island
Nephrolepidaceae	*Nephrolepis exaltata* (L.) Schott	I		n/a	Not distinguished from other *Nephrolepis*
Nephrolepidaceae	*Nephrolepis hirsutula* (Forst. f.) Presl	I	X	A	Most common ground cover in *Casuarina* forest
Nephrolepidaceae	*Nephrolepis multiflora* (Roxb.) Jarrett ex Morton	I		n/a	Not distinguished from other *Nephrolepis*
Ophioglossaceae	*Ophioglossum nudicaule* L. f.	I	X	U	Near airfield, localized, appeared after heavy rain (New record for Pagan)
Polypodiaceae	*Phymatosorus scolopendria* (Burm f.) Pic.-Serm.* (Syn: *Polypodium scolopendria*)	I	X	C	Scattered in native and coconut forest, epiphytic and on rocks
Psilotaceae	*Psilotum nudum* L.	I	X	U	Southern Pagan

Group/Family	Scientific Name	Status	Observed 2010	Abundance	Localities observed 2010/Notes
Pteridaceae	*Acrostichum aureum* L.	I		n/a	Not seen, no longer present at lake
Pteridaceae	*Pityrogramma calomelanos* (L.) Link	A	X	C	Roadsides and disturbed areas
Pteridaceae	*Pteris boninensis* H. Ohba	I		n/a	Not seen, listed by Raulerson 2006
Pteridaceae	*Pteris fauriei* Hieron.	I		n/a	Not seen, listed by Raulerson 2006
Pteridaceae	*Pteris quadriaurita* Retz.	I	X	C	Most common fern of forests, on most transects
Pteridaceae	*Pteris vittata* L.	A	X	C	Common on edge of lava, south and west part of Northern Pagan
Selaginellaceae	*Selaginella ciliaris* (Retz.) Spring	I		n/a	Not seen, last collected in 1996
Sinopteridaceae	*Cheilanthes tenuifolia* (Burm. f.) Sw.	I	X	C	Common in rocky substrates of forests
Thelypteridaceae	*Christella parasitica* (L.) H. Lev. * Syn: *Thelypteris parasitica*)	I	X	R	Isthmus, in swordgrass (New record for Pagan)
Thelypteridaceae	*Cyclosorus interruptus* (Willd.) H. Ito* (Syn: *Thelypteris interrupta*)	I	X	R	Southern Pagan ravine, only one site (New record for Pagan)
Thelypteridaceae	*Macrothelypteris torresiana* (Gaudich.) Ching* (Syn: *Thelypteris torresiana*)	I	X	U	Seen on roadside north of camp and Southern Pagan
Thelypteridaceae	*Sphaerostephanos unitus* (L.) Holttum* (Syn: *Thelypteris unita*)	I	X	R	Only on Southern Pagan near peaks
GYMNOSPERMS					
Cycadaceae	*Cycas circinalis* L.	I	X	R	Localized in ravines of Southern Pagan (New record for Pagan)
FLOWERING PLANTS - DICOTYLEDONS					
Acanthaceae	*Blechum pyramidatum* (Lam.) Urb.* (Syn: *Blechum brownei*)	A	X	U	Near old caldera wall TR1 and roadside north of camp (New record for Pagan)
Acanthaceae	*Ruellia prostrata* Poir.*	A	X	U, lc	Beach at camp, roadside, caldera wall (New record for Pagan)

Group/Family	Scientific Name	Status	**Observed 2010**	Abundance	**Localities observed 2010/Notes**
Aizoaceae	*Sesuvium portulacastrum* L.	I	X	R	Seen once on southern Pagan
Amaranthaceae	*Achyranthes aspera* L.	A	X	O	Scattered in disturbed areas of northern Pagan
Amaranthaceae	*Amaranthus spinosus* L.	A	X	O	Few plants in disturbed areas east of camp and grassland of northern Pagan
Amaranthaceae	*Amaranthus viridus* L.	A	X	U	Uncommon in disturbed areas of northern Pagan and high elevation southern Pagan
Anacardiaceae	*Mangifera indica* L.	A	X	U	Common along bottom of old caldera wall and at lower lake
Annonaceae	*Guamia mariannae* (Safford) Merr.	I	X	R	Seen few times east of old caldera wall and in southern Pagan forests
Apiaceae	*Centella asiatica* (L.) Urb.	I	X	R	Seen once on southern Pagan near peaks
Apocynaceae	*Catharanthus roseus* (L.) G. Don	A	X	U	Patches in forest and grassland, south side of northern Pagan
Apocynaceae	*Cerbera odollam* Gaertn.* (Syn: *Cerbera dilatata*)	I	X	R	Seen once in coconut forest south of old caldera wall TR3
Apocynaceae	*Neisosperma oppositifolia* (Lam.) Fosb. & Sachet	I	X	C	Native forest and coconut groves, north and south
Apocynaceae	*Ochrosia mariannensis* A. DC.	I	X	C	Native forest and coconut groves, north and south
Apocynaceae	*Thevetia peruviana* (Pers.) K. Schum.	A	X	U	Roadside two sites, northwest side of northern Pagan
Araliaceae	*Polyscius macgillivray* (Seems.) Harms* (Syn: *Polyscius grandifolia*)	I		n/a	Not seen, listed by Fosberg *et al.*1975
Araliaceae	*Polyscius scutellaria* (Burm. f.) Fosb.	A	X	R	Planted at house near beach at camp
Asteraceae	*Ageratum conyzoides* L.	A	X	U	Southern Pagan near peaks and isthumus
Asteraceae	*Bidens alba* (L.) DC	A		n/a	Not seen, Raulerson 2006

Group/Family	Scientific Name	Status	Observed 2010	Abundance	Localities observed 2010/Notes
Asteraceae	*Bidens pilosa* L.	**A**	X	**O**	**Roadside north of camp**
Asteraceae	*Chromolaena odorata* (L.) R. M. King & H. Rob.* (Syn: *Eupatorium odoratum*)	A	X	C	Dominant ground cover in some open areas, uncommon on southern Pagan
Asteraceae	*Conyza bonariensis* (L.) Cronquist	A	X	R	Coconut forest of northern Pagan, isthmus
Asteraceae	*Conyza canadensis* (L.) Cronquist	A		n/a	Not seen, listed by Fosberg *et al*. 1975 from airstrip
Asteraceae	*Cyanthillium cinereum* (L.) H. Rob.* (Syn: *Vernonia cinerea*)	A	X	A	Found in vegetation throughout northern Pagan
Asteraceae	*Elephantopus mollis* Kunth	A	X	U	Southern Pagan near peaks and TR11
Asteraceae	*Emilia sonchifolia* (L.) DC	A	X	O	Scattered in coconut forest and edge of grasslands of northern Pagan
Asteraceae	*Glossogyne tannensis* (Spreng.) Garnock-Jones* (Syn: *Glossogyne tenuifolia*, *Glossocardia* sp.)	I	X	R	Southern Pagan, grassland near peaks
Asteraceae	*Lagenophora lanata* A. Cunn.*	I	X	R	Southern Pagan near peaks (New record for Pagan)
Asteraceae	*Mikania micrantha* Kunth* (Syn: *Mikania scandens*)	A	X	R	Ruins of mine building north of camp (New record for Pagan)
Asteraceae	*Synedrella nodiflora* (L.) Gaertn.	A		n/a	Not seen, listed by Fosberg *et al.* 1975
Asteraceae	*Tridax procumbens* L.	A	X	C	Common near air field and in grasslands of northern Pagan
Asteraceae	*Wollastonia* biflora (L.) DC* (Syn: *Wedelia biflora* var. *canescens*)	I		n/a	Not seen, listed by Fosberg *et al.* 1975, collected by Herbst east of village in 1984
Balanophoraceae	*Balanaophora fungosa* Forst.	I		n/a	Not seen, collected by Herbst east of village in 1984

Group/Family	Scientific Name	Status	Observed 2010	Abundance	Localities observed 2010/Notes
Bombacaceae	*Ceiba pentandra* (L.) Gaertn.	A	X	U	Patches on south slope of northern Pagan and at base of old caldera wall
Boraginaceae	*Cordia subcordata* Lam.	I	X	R	Southern Pagan TR 11 and cycad ravine (New record for Pagan)
Boraginaceae	*Heliotropium indicum* L.	I	X	**U**	South part of northernPagan, near Degusa Beach
Boraginaceae	*Heliotropium procumbens* Mill. var. *depressum* (Cham.) Fosb. & Sachet (Syn: *Heliotropium ovalifolium* var. *depressum*)	I	X	U	South slope of northern Pagan near old road
Boraginaceae	*Tournefortia argentea* L. f. (Syn: *Messerschmidia argentea*)	I		n/a	Not seen, listed by Fosberg 1958
Buddleiaceae	*Buddleia asiatica* Lour.	A	X	R	Seen once on side of road in northwest and by Eric Cook in SE of island in swordgrass ravine (New record for Pagan)
Capparaceae	*Capparis cordifolia* Lam.	I	X	R	Seen once on cliff of west side of southern Pagan, and on cliff at Inae Dikiki
Capparaceae	*Cleome viscosa* L.	A	X	U	Scattered in southern part of northern Island and roadside north of camp
Caprifoliaceae	*Sambucus mexicana* Presl ex DC	A		n/a	Not seen, listed by Raulerson 2006
Caricaceae	*Carica papaya* L.	A	X	C	Common in forest of north Pagan
Casuarinaceae	*Casuarina equisetifolia* L.* (Syn: *Casuarina litorea*)	I	X	A	Most common tree of northern Pagan, dominant of most forest
Clusiaceae	*Calophyllum inophyllum* L.	I	X	R	Uncommon on transect in northeast forest and at base of caldera wall

Group/Family	Scientific Name	Status	Observed 2010	Abundance	Localities observed 2010/Notes
Clusiaceae	*Mammea odorata* (Raf.) Kosterm. (Syn: *Ochrocarpos odoratus*)	I	X	R	Talague Beach and forests of northeast, also in southeast
Combretaceae	*Terminalia catappa* L.	I	X	C	Component of native and coconut forest in north and south
Convolvulaceae	*Ipomoea aquatica* Forsk.	A		n/a	Not seen, listed by Fosberg *et al*. 1975 from lake
Convolvulaceae	*Ipomoea batatas* (L.) Lam.	A		n/a	Not seen, listed by Fosberg *et al.* 1975 as cultivated
Convolvulaceae	*Ipomoea pes-caprae* (L.) VanOost. subsp. *brasiliensis*	I	X	C	Sand beaches and rocky areas near shore
Convolvulaceae	*Ipomoea triloba* L.	A	X	U	Roadside near old caldera wall and village ruins north of camp, TR4 (New record for Pagan)
Convolvulaceae	*Operculina ventricosa* (Bert.) Peter	A	X	U	Scattered on both north and south Pagan
Cucurbitataceae	*Coccinia grandis* (L.) Voigt	A	X	U	Northeast of camp on TR4 and roadside in northwest (New record for Pagan)
Cucurbitataceae	*Momordica charantia* L.	A	X	C	Abundant near camp and at village ruins
Euphorbiaceae	*Chamaesyce hirta* (L.) Millsp.* (Syn: *Euphorbia hirta*)	A	X	U	Scattered in disturbed areas of northern Pagan
Euphorbiaceae	*Chamaesyce hypericifolia* (L.) Millsp.* (Syn: *Euphorbia glomerifera*)	A	X	R	Seen once at ruins of mine building north of camp (New record for Pagan)
Euphorbiaceae	*Chamaesyce prostrata* (Aiton) Small* (Syn: *Euphorbia prostrata*)	A	X	C?	Mixed with *C. thymifolia*
Euphorbiaceae	*Chamesyce* cf. s*errulata** (Syn: *Euphorbia gaudichaudii, E. reinwardtiana*)	I	X	R	Southern Pagan TR 11 and cycad ravine (New record for Pagan)

Group/Family	Scientific Name	Status	Observed 2010	Abundance	Localities observed 2010/Notes
Euphorbiaceae	*Chamaesyce thymifolia* (L.) Millsp.* (Syn: *Euphorbia thymifolia*)	A	X	C	Common in disturbed areas and bare cinder patches of north
Euphorbiaceae	*Jatropha curcas* L.	A	X	C	Patches at base of old caldera wall and roadside
Euphorbiaceae	*Jatropha gossypifolia* L.	A	X	A	Common in grassland near air strip of northern Pagan
Euphorbiaceae	*Macaranga thompsonii* Merr.	I		n/a	Not seen, fossil record
Euphorbiaceae	*Manihot esculenta* Crantz	A cult		n/a	Not seen, Fosberg *et al.* 1975
Euphorbiaceae	*Melanolepis multiglandulosa* (Reinw. ex. Bl.) Reichb. f. & Zoll.	I	X	O	Component of native and coconut forests in north and south
Euphorbiaceae	*Phyllanthus acidus* (L.) Skeels	A	X	R	One tree planted in ruins of village north of camp (New record)
Euphorbiaceae	*Phyllanthus amarus* Sch. & Th.	A	X	C	Scattered and widespread on northern Pagan
Euphorbiaceae	*Phyllanthus debilis* Klein ex. Willd.	A		n/a	Not distinguished from *P. amarus*
Euphorbiaceae	*Phyllanthus marianus* Muell.-Arg.	I	X	U	Patches on rocky slopes at base of old caldera wall, scrub vegetation north of TR2, southern Pagan shrubland
Euphorbiaceae	*Phyllanthus* saffordii Merr.	I		n/a	Probably not present on Pagan
Euphorbiaceae	*Ricinus communis* L.	A	X	R	Only seen in ruins of village north of camp and the northern part of the isthmus (New record for Pagan)
Fabaceae	*Abrus precatorius* L.	A	X	C	Scattered in open forest of northern Pagan
Fabaceae	*Acacia confusa* Merr.	A	X	U	Patches (planted) seen near TR2 and east of air field

Group/Family	Scientific Name	Status	Observed 2010	Abundance	Localities observed 2010/Notes
Fabaceae	*Alysicarpus vaginalis* (L.) DC	A	X	C	Common in grasslands of northern Pagan
Fabaceae	*Atylosia scarabaeoides* (L.) Benth. (Syn: *Cantharospermum scarabaeoides)*	I	X	C	Common in scrub vegetation and in disturbed areas of northern Pagan
Fabaceae	*Bauhinia monandra* Kurz	A	X	O	Patches along roadside at base of old caldera wall
Fabaceae	*Caesalpinia major* (Medic) Dandy & Exell	I	X	R	Talague in north and ravine in south (New record for Pagan)
Fabaceae	*Calopogonium mucunoides* Desv.	A		n/a	Not seen, listed by Raulerson 2006
Fabaceae	*Canavalia megalantha* Merr. var. *falanruwae* Fosb.	I	X	R	Seen once in scrub vegetation north of TR2
Fabaceae	*Cassia fistula* L.	A		n/a	Not seen, collected by Herbst in 1984 near lakes
Fabaceae	*Chamaecrista leschenaultiana* (DC.) Degener* (Syn: *Cassia leschenaultiana*)	A		n/a	Not seen, perhaps the same as *C. mimusoides*
Fabaceae	*Chamaecrista mimosoides* (L.) E. Greene* (Syn: *Cassia mimusoides*)	A	X	U	South Island near peaks
Fabaceae	*Crotalaria pallida* Ait.	A	X	O	Scattered in disturbed areas and coconut forest of north
Fabaceae	*Crotalaria trifoliastrum* Willd.	A		n/a	Not seen, listed by Fosberg 1958
Fabaceae	*Cynometra ramiflora* L.	I	X	R	South Island native forest of cycad ravine (New record for Pagan and N. Marianas)
Fabaceae	*Delonix regia* (Boj.) Raf.	A	X	U	Sighted by Laura Williams and Eric Cook in gulch near Degusa
Fabaceae	*Derris elliptica* (Roxb.) Benth.	A		n/a	Not seen, collected by Herbst in 1984 near lakes
Fabaceae	*Desmanthus virgatus* (L.) Willd.	A	X	R	Near church of old village north of camp (New record for Pagan)

Group/Family	Scientific Name	Status	Observed 2010	Abundance	Localities observed 2010/Notes
Fabaceae	*Desmodium heterophyllum* (Willd.) DC	A		n/a	Not seen, listed by Raulerson 2006
Fabaceae	*Desmodium incanum* DC	A	X	C	Common in disturbed areas of northern part of island
Fabaceae	*Desmodium triflorum* (L.) DC	A	X	A	Common in grasslands and disturbed areas of northern Pagan
Fabaceae	*Erythrina variegata* var. *orientalis* (L.) Merr.	I	X	C	Present in remaining forest stands of north part of island
Fabaceae	*Glycine clandestina* Wendl.	A		n/a	Not seen, listed by Fosberg *et al.* 1975
Fabaceae	*Leucaena leucocephala* (Lam.) De Wit (Syn: *Leucaena latisiliqua*)	A	X	C	Scattered and patchy at base of old caldera wall and south part of northernPagan
Fabaceae	*Mucuna gigantea* (Willd.) DC.	I		n/a	Not seen, listed by Fosberg *et al*. 1975, collected in 1930s
Fabaceae	*Pithecellobium dulce* (Roxb.) Benth.	A	X	U	Few trees seen at base of old caldera wall and near Degusa
Fabaceae	*Senna occidentalis* (L.) Link* (Syn: *Cassia occidentalis*)	A	X	U?	Isthmus and northern Pagan, less common than *S. obtusifolia*
Fabaceae	*Senna obtusifolia* (L.) H. Irwin & Barneby* (Syn: *Cassia obtusifolia*, *C. tora*)	A	X	C	Forests and grasslands of south part of North Island (Possible new record for Pagan)
Fabaceae	*Sophora tomentosa* L.	I		n/a	Not seen, listed by Raulerson 2006
Fabaceae	*Vigna marina* (Burm.) Merr.	I		n/a	Not seen, listed by Fosberg *et al.* 1975 from lakes, isthmus, beach
Fabaceae	*Vigna unguiculata* (L.) Walp.	A		n/a	Not seen, listed by Raulerson 2006
Goodeniaceae	*Scaevola taccada* (Roxb.) Gaertn. (Syn: *Scaevola sericea, S. frutescens*)	I	X	R	Cliffs above Talague, sea cliffs of southern Pagan

Group/Family	Scientific Name	Status	Observed 2010	Abundance	Localities observed 2010/Notes
Hernandiaceae	*Hernandia sonora* L. (Syn: *Hernandia nymphaeaefolia*)	I	X	R	Near Lake Sinhayong and in coconut forest of north
Lamiaceae	*Hyptis capitata* Jacq.	A		n/a	Not seen, listed by Fosberg 1958
Lamiaceae	*Hyptis pectinata* (L.) Poit.	A	X	U	Edges of forest and roadside near TR 1 and 2
Lamiaceae	*Ocmium sanctum* L.	I	X	R	Cultivated and escaped at houses near camp
Lauraceae	*Cassytha filiformis* L.	I	X	U	Roadside northernPagan west side
Lauraceae	*Persea americana* Mill.	A	X	U	Few trees seen at base of old caldera wall TR1
Lecythidaceae	*Barringtonia asiatica* (L.) Kurz	I	X	C	Coconut forest of both northern and southern Pagan
Loganiaceae	*Geniostoma micranthum* A. DC var. *paganense* Fosb.	I		n/a	***G. micranthum* may now be a synonym of *G. rupestre***
Loganiaceae	*Geniostoma rupestre* J. R. & G. Forst. var. *glaberrimum* (Benth.) Conn*	I	X	U	Southern Pagan native forest and isthmus
Lythraceae	*Pemphis acidula* Forst. f.	I	X	R	On cliffs at Inae Dikiki
Malvaceae	*Abelmoschus moschatus* Medik.* (Syn: *Hibiscus abelmoschus*)	A	X	R?	Sighted by Eric Cook on isthmus (New record for Pagan)
Malvaceae	*Abutilon indicum* (L.) Sweet	I?	X	R	Northwest of island, open coconut forest (New record for Pagan)
Malvaceae	*Gossypium hirsutum* L. var. *marie-galante* (Watt) Hutchinson	A		n/a	Not seen, listed by Fosberg *et al.* 1975 from isthmus
Malvaceae	*Hibiscus tiliaceus* L.	I	X	C	Native forest of both northern and southern Pagan
Malvaceae	*Malvastrum coromandelianum* (L.) Garcke	A		n/a	Not seen, listed by Raulerson 2006
Malvaceae	*Sida acuta* Burm. f.	A	X	C	Grassland and disturbed areas of northern Pagan
Malvaceae	*Sida rhombifolia* L.	A	X	U	Few plants seen south slope of northern Pagan

Group/Family	Scientific Name	Status	Observed 2010	Abundance	Localities observed 2010/Notes
Malvaceae	*Thespesia populnea* (L.) Sol. ex. Correa	I	X	U	Talague Beach, TR 7.
Malvaceae	*Urena lobata* L..var. *sinuata* (L.) Gagnep.	I	X	C	Common in coconut forest and mixed forest of north, sterile. Not listed by Raulerson 2006, but listed by Fosberg 1958
Melastomataceae	*Melastoma malabathricum* L. var. *mariannnum* (Naudin) Fosb. & Sachet	I	X	U	Southern Pagan near peaks
Meliaceae	*Aglaia mariannensis* Merr.	I	X	C	Native forest of both northern and southern Pagan
Moraceae	*Artocarpus altilis* (Park.) Fosb.	Cham, A	X	U	Coconut forest of both north and south
Moraceae	*Artocarpus mariannensis* Trec.	I		n/a	Not seen, reported by CNMI biologists 2000
Moraceae	*Ficus benghalensis* L.	A		n/a	Not seen, listed by Fosberg *et al.* 1975, cultivated
Moraceae	*Ficus prolixa* Forst. f. var. *carolinensis* (Warb.) Fosb. (Syn: *Ficus saffordii*)	I	X	C	Common in native and *Casuarina* forest of north and south
Moraceae	*Ficus prolixa* Forst. f. var. *subcordata* Comer	I		n/a	Not distinguished from other *F. prolixa*, listed by Raulerson 2006
Moraceae	*Ficus tinctoria* Forst. f. var. *neo-ebudarum* (Summerh.) Fosb.	I	X	C	Common in native and *Casuarina* forest
Muntingiaceae (Tiliaceae)	*Muntingia calabura* L.	A	X	U	Roadside north of camp in gulch
Myoporaceae	*Myoporum boninense* Koidzumi	I	X	R	Seen once on eastern shore of southern Pagan
Myrsinaceae	*Discocalyx megacarpa* Merr.	I		n/a	Not seen, listed by Fosberg 1958
Myrtaceae	*Eugenia palumbis* Merr.	I	X	C	Common in native forest of northern Pagan and southeast
Myrtaceae	*Eugenia reinwardtiana* (Bl.) DC	I		n/a	Not seen, perhaps listed in error from Pagan

Group/Family	Scientific Name	Status	Observed 2010	Abundance	Localities observed 2010/Notes
Myrtaceae	*Eugenia uniflora* L.	A	X	R	One sterile plant near ruins of mine building north of camp (New record for Pagan)
Myrtaceae	*Psidium guajava* L.	A	X	C	Common in northwest section of island
Nyctaginaceae	*Boerhavia* sp.	I	X	R	One sterile plant seen at Inae Dikiki (New record for Pagan)
Nyctaginaceae	*Pisonia grandis* R. Br.	I	X	R	Few trees on plateau, cycad ravine, and east coast of southern Pagan (New record)
Oleaceae	*Jasminum marianum* DC	I	X	C	Common in native forest of northern and southern Pagan
Oxalidaceae	*Averrhoa carambola* L.	A	X	R	One sterile tree near ruins of mine building north of camp, also listed by Raulerson 2006
Oxalidaceae	*Oxalis corniculata* L.	A	X	U	Scattered in disturbed areas of northern Pagan
Passifloraceae	*Passiflora foetida* L. var. *hispida* (DC) Killip	A	X	R	Seen rarely in disturbed areas east of camp
Passifloraceae	*Passiflora suberosa* L.	A	X	R	Collected at ruin of mine building north of camp (New record for Pagan)
Piperaceae	*Peperomia mariannensis* C.DC. f. *mariannensis*	I		n/a	Not seen, listed by Fosberg *et al.* 1975
Piperaceae	*Piper betle* L.	I	X	R	Rare on southern Pagan near *Areca* palms, perhaps planted, listed by Raulerson 2006
Polygonaceae	*Antigonon leptopus* H. & A.	A	X	U	Few disturbed areas near camp and old village, listed by Raulerson 2006
Portulacaceae	*Portulaca australis* Endl. (Syn: *Portulaca samoensis*)	I	X	R	Seen only near the coast at Inae Dikiki

Group/Family	Scientific Name	Status	Observed 2010	Abundance	Localities observed 2010/Notes
Portulacaceae	*Portulaca lutea* Sol. ex. Forst. f.	I	X	U	Near coast at Inae Dikiki and Degusa Beach
Portulacaceae	*Portulaca oleracea* L. var. *granulato-stellata* v. Poelln.	I	X	U	Near coast at Inae Dikiki and Degusa and in grassland of northern Pagan
Portulacaceae	*Portulaca pilosa* L.	A	X	C	Common in grasslands of northern Pagan
Primulaceae	*Lysimachia mauritiana* Lam.	I	X	R	Seen at Talague and reported from southern Pagan by J. Lepson
Rhamnaceae	*Colubrina asiatica* (L.) Brongn.	I	X	C	Common in native forest of north and south
Rubiaceae	*Aidia cochinchinensis* Lour. (Syn: *Randia cochinchinensis*)	I	X	R	Rare in native forest of southern Pagan
Rubiaceae	*Hedyotis biflora* (L.) Lam.	I		n/a	Not seen, listed by Raulerson 2006
Rubiaceae	*Hedyotis corymbosa* (L.) Lam.	A	X	C	Common in disturbed areas of northern Pagan
Rubiaceae	*Hedyotis foetida* (Forst. f.) J. E. Sm. var. *mariannensis* (Merr.) Fosb.	I	X	U	Climbing on cliffs of old caldera wall
Rubiaceae	*Hedyotis scabridifolia* Kaneh.	I		n/a	Not seen, listed from Mt. Pagan by Fosberg *et al.* 1975
Rubiaceae	*Morinda citrifolia* L. var. *citrifolia*	I	X	C	Common in native, coconut and *Casuarina* forest
Rubiaceae	*Psychotria mariana* Bartl. ex. DC	I	X	C	Common in native forest and scrub of north and south
Rubiaceae	*Spermacoce assurgens* Ruiz & Pav. (Syn: *Borreria laevis*)	A	X	U	Scattered in bomb craters and disturbed area near air field (New record for Pagan)
Rutaceae	*Citrus aurantifolia* (Christm.) Swingle	A	X	U	Planted and persisting near village and old caldera wall of north Pagan
Rutaceae	*Citrus reticulata* Blanco	A	X	U	Planted trees in old village

Group/Family	Scientific Name	Status	Observed 2010	Abundance	Localities observed 2010/Notes
Rutaceae	*Triphasia trifolia* (Burm. f.) P. Wils.	A	X	C, lc	Localized in *Casuarina* forest near old village site
Sapindaceae	*Cardiospermum halicacabum* L.	A	X	U	Roadside north of camp near village ruins (New record for Pagan)
Sapindaceae	*Dodonaea viscosa* (L.) Jacq.	I	X	C, lc	Common in scrub vegetation of north and found at high elevation on southern Pagan
Sapindaceae	*Tristiropsis obtusangula* Radlk. (Syn: *Tristiropsis acutangula*)	I		n/a	Not seen, fossil record (Fosberg and Corwin 1958).
Sapotaceae	*Pouteria obovata* (R. Br.) Baehni	I	X	C	Common in native forest of north and south
Scrophulariaceae	*Bacopa procumbens* (Mill.) Greenm.	A		n/a	Not seen, collected by Herbst east of village in 1984
Scrophulariaceae	*Lindernia crustacea* (L.) F. Muell.	I		n/a	Not seen, listed by Fosberg *et al*. 1975 from Mt. Pagan
Solanaceae	*Capsicum frutescens* L.	A	X	U	In old village, along road at base of caldera wall
Solanaceae	*Nicotiana tabacum* L.	A	X	R	South side of northern Pagan and near ruins north of Inae Dikiki
Solanaceae	*Physalis minima* L.	I	X	U	Southern Pagan in swordgrass ravine, sighted by Eric Cook, listed by Raulerson 2006
Sterculiaceae	*Melochia villosissima* (Presl.) Merr. var. *compacta* Hochr.* (Syn: *Melochia compacta*)	I		n/a	This variety not seen, listed by Fosberg *et al*. 1975
Sterculiaceae	*Melochia villosissima* (Presl.) Merr. var. *villosissima*	I	X	R	One seen on southern Pagan, in cycad ravine
Sterculiaceae	*Melochia compacta* x *villosissima?*	I		n/a	Not seen, listed by Raulerson 2006
Sterculiaceae	*Waltheria indica* L.	A	X	O	Scattered in grassland and scrub vegetation of northern Pagan, collected by Herbst in 1984

Group/Family	Scientific Name	Status	Observed 2010	Abundance	Localities observed 2010/Notes
Theaceae	*Eurya japonica* Thunb. var. *nitida* (Korth.) This.-Dyer	I	X	R	Few seen on southern Pagan and isthmus
Tiliaceae (Elaeocarpaceae)	*Elaeocarpus joga* Merr.	I	X	U	Large trees in native forest of southern Pagan and inside crater near peaks
Tiliaceae	*Grewia crenata* (L. f.) Schinz & Guillaumin	I	X	U	Uncommon in native forest of north and south
Tiliaceae	*Triumfetta procumbens* Forst. f.	I		n/a	Not seen, listed by Fosberg *et al*. 1975 from Inae Dikiki
Tiliaceae	*Triumfetta semitriloba* Jacq.	A	X	C	Common in coconut forest, sterile
Ulmaceae	*Trema orientalis* (L.) Bl. var. *argentea* (Pl.) Laut.	I	X	U	Uncommon in native forest of north and south
Ulmaceae	*Trema orientalis* (L.) Bl. var. *viridis* Laut.	I	X	U	Uncommon in native forest of northern Pagan, caldera wall
Urticaceae	*Boehmeria celebica* Bl.	I		n/a	Not seen, Fosberg *et al*. 1975 considered this questionable
Urticaceae	*Boehmeria densiflora* H. & A.	I		n/a	Not seen, listed by Fosberg *et al*. 1975 from Mt. Pagan
Urticaceae	*Pipturus argenteus* (Forst. f.) Wedd. var. *argenteus*	I	X	O	Scattered in native forest and cliffs of northern Pagan
Verbenaceae	*Callicarpa candicans* (Burm. F.) Hochr. var. *paucinervia* (Merr.) Fosb.	I	X	U	Cliffs behind beach at Talague and Degusa
Verbenaceae	*Callicarpa lamii* Hosokawa	I		n/a	Not seen, listed by Fosberg *et al*. 1975 from north of marine camp
Verbenaceae	*Clerodendrum buchananii* (Roxb.) Walp. var. *fallax* (Lindl.) Bakh.	I	X	C	Scattered in forest at base of caldera wall and in coconut forest at Degusa
Verbenaceae	*Clerodendrum inerme* (L.) Gaertn. var. *oceanicum* A. Gray	I	X	C	Common at base of caldera wall, near camp, and southeast
Verbenaceae	*Lantana camara* L.	A	X	R	One patch seen northeast of camp (New record for Pagan)

Group/Family	Scientific Name	Status	Observed 2010	Abundance	Localities observed 2010/Notes
Verbenaceae	*Premna serratifolia* L.* (Syn: *Premna obtusifolia*)	I	X	U	Component of remaining native forest in north and south
Verbenaceae	*Stachytarpheta jamaicensis* (L.) Vahl	A	X	C	Common in grasslands of northern Pagan and near air field
Verbenaceae	*Vitex negundo* L. var. *bicolor* (Willd.) Lam. (Syn: *Vitex trifolia* var. *bicolor*)	I	X	U	Few plants at Talague, patches near Inae Dikiki
FLOWERING PLANTS -	**MONOCOTYLEDONS**				
Agavaceae	*Agave americana* L.	A	X	R	Persisting from cultivation at beach house (variegated form) and roadside (blue leaves)
Agavaceae	*Agave rigida* Mill. var. rigida	A		n/a	Not seen perhaps same as *A. sisalana*
Agavaceae	*Agave sisalana* Perrine* (Syn: *Agave rigida* var. *sisalana*)	A		n/a	Not seen, listed by Fosberg *et al.* 1975 from isthmus
Araceae	*Alocasia macrorrhizos* (L.) G. Don*	Cham	X	R	Few persisting in coconut forest in northeast and south
Araceae	*Colocasia esculenta* (L.) Schott	Cham		n/a	Not seen, listed by Fosberg *et al*. 1975 from lake
Araceae	*Xanthosoma sagittifolium* (L.) Schott	A, cult	X	R	Few persisting in coconut forest, only seen on southernPagan
Arecaceae	*Areca catechu* L.	Cham, A	X	R	Few patches on southern Pagan (TR11 and ravines)
Arecaceae	*Cocos nucifera* L.	Cham?, A, cult	X	A	Abundant in former coconut plantations and adjacent forests
Bromeliaceae	*Anana comosus* (L.) Merr.	A		n/a	Not seen, listed by Fosberg *et al*. 1975 from lake and north of marine camp
Cannaceae	*Canna* sp.	A	X	R	Sterile plant in ruins of village north of camp (New record)

Group/Family	Scientific Name	Status	Observed 2010	Abundance	Localities observed 2010/Notes
Commelinaceae	*Commelina benghalensis* L.	A	X	R	Roadside near base of caldera wall
Cyperaceae	*Cyperus compressus* L.	A	X	U	Sterile plants near shore at camp were probably this species
Cyperaceae	*Cyperus cyperinus* (Retz.) Suringar	I	X	C	Occasional, native and coconut forest in north and south
Cyperaceae	*Cyperus javanicus* Houtt.	I	X	A	Common sedge in open forests, coconut plantations and near shore
Cyperaceae	*Cyperus polystachyos* Rottb.	I	X	C	Common on roadsides, open areas
Cyperaceae	*Cyperus rotundus* L.	A	X	U	Near camp, sterile
Cyperaceae	*Fimbristylis boninensis* Hayata	I		n/a	Not seen, listed by Fosberg *et al.* 1975 from North Island
Cyperaceae	*Fimbristylis cymosa* R. Br.	I	X	C	Common near shore, at lake, and in scrub vegetation
Cyperaceae	*Fimbristylis dichotoma* (L.) Vahl	I	X	C	Scattered in native and coconut forest, most common *Fimbristylis* seen, in north & south
Cyperaceae	*Kyllinga brevifolia* Rottb.* (Syn: *Cyperus brevifolius*)	I	X	U	Isthmus grassland, roadside north of camp
Cyperaceae	*Kyllinga nemoralis* (J. R. Forst. & G.Forst.) Dandy ex Hutchinson & Dalziel* (Syn: *Cyperus kyllingia*)	I		n/a	Not seen, listed by Raulerson 2006
Cyperaceae	*Scleria lithosperma* (L.) Swartz	I	X	C	Native forest both north and south
Dioscoraceae	*Dioscorea esculenta* (Lour.) Burk. var. *tiliaefolia* (Kunth.) Fosb. & Sachet	I		n/a	Not seen, listed by Fosberg *et al*. 1975, 1986 from literature
Dioscoraceae	*Dioscorea nummularia* Lam.	A		n/a	Not seen, listed by Fosberg *et al.* 1975 from literature

Group/Family	Scientific Name	Status	Observed 2010	Abundance	Localities observed 2010/Notes
Flagellariaceae	*Flagellaria indica* L.	I		n/a	Not seen, collected by Herbst in 1984 east of village
Liliaceae	*Asparagus* cf. *densiflorus* (Kunth.) Jessop	A	X	R	Ornamental in pot at church in village north of camp, sterile (New record for Pagan)
Liliaceae	*Crinum asiaticum* L.	A	X	R	One plant seen at Talague on cliff, not flowering, collected by Rinehart 1996
Liliaceae	*Crinum macrantherum* Engl.	A		n/a	Listed as doubtful by Fosberg *et al.* 1975, perhaps same as *Crinum asiaticum*
Liliaceae	*Curculigo orchioides* Gaertn.	I		n/a	Not seen, listed by Fosberg *et al.* 1975, last collected in 1930s
Liliaceae	*Dianella ensifolia* (L.) DC	I		n/a	Not seen; fossil record only (Fosberg and Corwin 1958)
Liliaceae	*Hymenocallis littoralis* (Jacq.) Salisb.	A	X	C	Common near shore and near Sanhalom Lake
Liliaceae	*Sanseviera trifasciata* Prain	A		n/a	Not seen, listed by Raulerson 2006
Musaceae	*Musa* x *sapientum* L.	Cham, A	X	R	Seen once in crater on southern Pagan
Orchidaceae	*Spathoglottis* sp.	I		n/a	Not seen; fossil record only (Fosberg and Corwin 1958)
Orchidaceae	*Taeniophyllum marianense* Schltr.	I	X	U	Southern Pagan, epiphytic, first listed by Raulerson 2006
Pandanaceae	*Freycinetia reineckei* Warb.	I	X	U	Southern Pagan, forests and ravines
Pandanaceae	*Pandanus dubius* Spreng.	I		n/a	Not seen, listed by Fosberg 1958
Pandanaceae	*Pandanus tectorius* Park.	I	X	C	Common in native patches within *Casuarina* forest
Poaceae	*Axonopus compressus* (Sw.) Beauv.	A	X	O	Near old caldera wall (New record for Pagan)

Group/Family	Scientific Name	Status	Observed 2010	Abundance	Localities observed 2010/Notes
Poaceae	*Bambusa vulgaris* Schrad. ex Wendl.	A		n/a	Not seen, listed by Fosberg *et al*. 1975 from village
Poaceae	*Bothriochloa bladhii* (Retz.) S. T. Blake* (Syn: *Dicanthium bladhii*)	A	X	C	Common on roadsides and grasslands of south part of northern Pagan
Poaceae	*Cenchrus brownii* R. & S.	A		n/a	Not seen, listed by Fosberg *et al*. 1975 from marine camp
Poaceae	*Cenchrus echinatus* L.	A		n/a	Not seen, listed by Fosberg *et al*. 1975 from village and isthmus
Poaceae	*Chloris barbata* (L.) Sw.	A	X	O	Occasional roadside and open areas
Poaceae	*Chrysopogon aciculatus* (Retz) Trin.	I	X	A	Common in grassland of northern Pagan
Poaceae	*Cynodon dactylon* L. (Syn: *Cynodon dactylon* var. *parviglumis*)	A	X	C	Common near camp and air field
Poaceae	*Dactylotenium aegyptium* (L.) Willd.	A	X	C	Common on sand near shore and disturbed areas
Poaceae	*Digitaria bicornis* (Lam.) R. & S.	A		n/a	Not seen, listed by Raulerson 2006
Poaceae	*Digitaria ciliaris* (Retz.) Koel.	I	X	U?	Mixed with other *Digitaria* spp.
Poaceae	*Digitaria gaudichaudii* (Kunth) Buse	I		n/a	Not seen, listed by Raulerson 2006
Poaceae	*Digitaria radicosa* (J. S. Presl) Miq.	I	X	C?	Probably most common *Digitaria* of coconut and native forests
Poaceae	*Digitaria setigera* Roth	I	X	U	Uncommon roadside and forest at base of old caldera wall
Poaceae	*Eleusine indica* (L.) Gaertn.	A	X	U	Uncommon, seen only on isthmus
Poaceae	*Eragrostis ciliaris* (L.) R. Br.	A	X	U	Uncommon, seen only on isthmus and southern Pagan
Poaceae	*Eragrostis tenella* (L.) P. Beauv. ex Roem. & Schult.* (Syn: *Eragrostis amabilis*)	I		n/a	Not seen, listed by Fosberg *et al.* 1975 from isthmus and lake

Group/Family	Scientific Name	Status	Observed 2010	Abundance	Localities observed 2010/Notes
Poaceae	*Garnotia stricta* Brongn. (Unknown bunchgrass)	I	X	C	Common in open areas of native, *Casuarina*, and coconut forest of southern Pagan
Poaceae	*Heteropogon contortus* (L.) P. Beauv.	I	X	U	Uncommon, localized in scrub in north and steep slopes in south
Poaceae	*Ischaemum longisetum* Merr.* (Syn: *Ischaemum longisetum* var. *raulersoniae*)	I	X	R	Rare, only on southern Pagan near peaks
Poaceae	*Lepturus repens* (Forst. F.) R. Br.* (Syn: *Lepturus repens* var. *subulatus* Fosb.)	I		n/a	Not seen, listed by Fosberg *et al*. 1975, collected by Herbst east of village in 1984
Poaceae	*Miscanthus floridulus* (Labill.) Warb. ex K. Schum. & Laut.	I	X	A	Abundant on isthmus and southern Pagan, patchy in northern part of island
Poaceae	*Paspalum conjugatum* Berg.	A	X	R	Seen once near Sanhalom Lake
Poaceae	*Paspalum scrobiculatum* L.* (Syn: *Paspalum cartilagineum*, *Paspalum commersonii*, *Paspalum orbiculare*)	A?	X	U	Uncommon, only on southern Pagan near peaks and plateau forest
Poaceae	*Paspalum vaginatum* Sw.* (Syn: *Paspalum distichum*)	I	X	U	Localized on edge of Sanhiyong Lake
Poaceae	*Pennisetum purpureum* Schumach.	A		n/a	Not seen, listed by Fosberg *et al.* 1975 from Sanhiyong Lake
Poaceae	*Setaria parviflora* (Poir.) Kerguelen* (Syn: *Setaria geniculata*)	A	X	U	Uncommon, southern Pagan and isthmus
Poaceae	*Setaria pumila* (Poir.) Roem. & Schult.* (Syn: *Setaria pallide-fusca*)	I		n/a	Not seen, listed by Fosberg *et al*. 1986
Poaceae	*Sporobolus diandrus* (Retz.) P. Beauv. (Syn: *Sporobolus diander*)	A	X	U	Uncommon, on roadsides of northern Pagan
Poaceae	*Sporobolus fertilis* (Steud.) Clayton (Syn: *Sporobolus indicus* var. *fertilis*)	I	X	C	Common in grasslands of north and open areas of northwest
Poaceae	*Sporobolus virginicus* (L.) Kunth	I	X	R	Seen once sterile on beach side of Sanhiyong Lake

Group/Family	Scientific Name	Status	Observed 2010	Abundance	Localities observed 2010/Notes
Poaceae	*Sporobolus* sp.	?	X	O	Scattered in coconut and native forests of north and south
Poaceae	*Stenotaphrum micranthum* (Desv.) Hubb.	I		n/a	Not seen, listed by Fosberg *et al.* 1986
Poaceae	*Thuarea involuta* (Forst. f.) R. Br. ex. R. & S.	I		n/a	Not seen, listed by Fosberg *et al.* 1986, found in the strand
Poaceae	*Zea mays* L.	A		n/a	Not seen, listed by Fosberg *et al*. 1975 as cultivated
Poaceae	*Zoysia matrella* (L.) Merr. var.*matrella*	I	X	C	Near shore west and south side of northern Pagan
Poaceae	*Zoysia matrella* (L.) Merr. var. *pacifica* Goudsw. (Syn: *Zoysia tenuifolia*)	I		n/a	Varieites not distinguished
Poaceae	*Urochloa glumaris* (Trin.) Veldkamp* (Syn: *Panicum ambiguum*)	I		n/a	Not seen, listed by Fosberg *et al*. 1975 near landing
Poaceae	*Urochloa subquadripara* (Trin.)R. D. Webster* (Syn: *Brachiaria subquadripara, Panicum subquadriparum*)	I	X	R	Seen once in native forest near base of old caldera wall
Taccaceae	*Tacca leontopetaloides* (L.) O. Ktze	Cham		n/a	Not seen, listed by Fosberg *et al*. 1975 from south slope of northern Pagan

* Nomenclature from Clayton and Snow 2010 (grasses), Palmer 2003, Holttum 1977 (ferns), Wagner *et al.* 1999 (alien flowering plants and sedges), and Raulerson 2006 or specimen annotations in Bishop Museum *Herbarium Pacificum* (indigenous flowering plants). Otherwise, scientific names and status are from Fosberg *et al.* 1979, 1982, 1986.

Status: A, Alien; Cham, Chamorro (aboriginal) Introduction; I, Indigenous to Pagan and the Mariana Islands (includes Marianas endemics); ?, Unknown; cult, cultivated or persisting from former cultivation.

Abundance: A, Abundant; C, Common; O, Occasional; U, Uncommon; R, Rare; lc, localized; n/a, Not applicable, not seen.